





THE AUTOMOBILE HANDBOOK

A CONVENIENT REFERENCE BOOK

for

Automobile Owners, Chauffeurs, Automobile
Repairmen, Garage Owners, Automobile
Salesmen, and All Other Persons
Interested in Self-Propelled,
Internal - Combustion-
Engine Vehicles

BY

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PREFACE

The rapid growth of the automobile industry and the consequent demand for information on the construction and operation of motor cars, has induced us to publish the Automobile Handbook, which will be found to contain such data as are most useful, not only to the chauffeur and repairman, but also to the owner and salesman. This handbook will be found invaluable to the driver or owner who wishes to take care of his own car and thus avoid the expense of outside help. It contains practical information on automobile troubles and remedies in such form as to be readily available.

In order to keep the handbook within a convenient size, many subjects are treated rather briefly, but the most important are given ample space. Wherever it has been found necessary to make use of illustrations of actual parts, they have been taken from the latest models of cars or auxiliaries, so that the handbook is strictly up to date. The illustrations will be found especially useful to the driver or owner who wishes to obtain a comprehensive knowledge of the construction and operation of automobile engines, transmission mechanism, carbureters, etc. Such tables as are

desirable have been inserted, and these have been carefully checked with regard to their correctness. Excerpts from the automobile laws of all the states of the Union are herein published for the benefit of those going from one state to another. In a number of cases tables or other data were secured from the manufacturers of cars or parts, and we wish at this time to express our appreciation of the assistance thus obtained.

INTERNATIONAL CORRESPONDENCE SCHOOLS

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The Automobile Handbook

GASOLINE AUTOMOBILES

RUNNING GEAR AND BODIES

GENERAL ASSEMBLY OF PARTS

There are two principal parts to an automobile, namely, the *chassis* (pronounced *shah-see*), and the *body*. The term chassis was originally used to designate only the frame of the automobile, but as now used it applies to the assembly of the running gear, consisting of wheels, axles, springs, and frame, and the power plant, which includes the engine and transmission. In other words, the chassis includes everything but the body and its accessories.

The assembly of a typical automobile having a touring body is shown in Fig. 1. Just in front of the driver's seat *a*, at the left side of the automobile, is a steering wheel *b* at the top of the steering column *c*. The guiding of the car is accomplished by rotating this wheel by hand, thus moving the front road wheels *d*, so as to turn them sidewise and change the direction of travel of the car.

Two large pedals project upwards through the floor of the car in front of the driver. The one on the left is for disengaging the engine from the driving mechanism; the one on the right is for applying brakes to stop the car. Each pedal is operated by the driver's foot. There are usually two smaller pedals

placed conveniently within reach of the driver's foot. One of these, called the *accelerator*, is used for regulating the speed of the engine, and hence of the car, by the foot of the driver. The second small pedal, called the *muffler cut-out pedal*, is used for permitting the exhaust from the engine to escape temporarily directly into the atmosphere, which makes it easy for the driver to discover any lack of regularity in the explosions occurring in the engine cylinders.

At the center of the car and just forwards of the driver's seat are two control levers. One is for applying brakes to stop the car, and hence is called the *brake lever*; the other is for adjusting the power-transmitting mechanism, so that the speed of travel of the car can be varied through a greater range than that obtainable in the engine, and also for driving the car backwards; this lever is called the *gear-shift lever*.

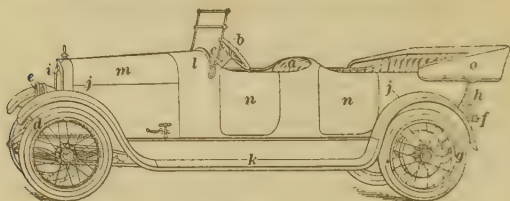


FIG. 1

Just under the steering wheel are small levers for controlling the power and speed of the engine. Each of these is attached to a shaft, or tube, that extends down alongside or inside the steering column that supports the steering wheel. One of the levers is for regulating the amount of fuel delivered to the engine, and is called the *throttle lever*; the other is for regulating the time at which the fuel is ignited, and is called the *spark lever*, or *spark control*.

Two lamps *e*, called *head lamps*, are placed at the extreme front of the car, at about the level of the tops of the road wheels. These lamps, in modern cars, contain electric bulbs to which current is supplied by a storage battery working in

conjunction with an electric generator. A *tail lamp f*, showing a red light to the rear and a white light at right angles to the car body, is carried on a suitable bracket at the rear of the car.

The car is driven by the rear wheels *g* and steered by the front wheels *d*; both sets of wheels are equipped with pneumatic tires. One or more spare tires, as *h*, for instance, are carried at the rear of the car.

The *radiator i* cools the water used for keeping the engine cool.

The seats, floor, and attached parts form the *body* of the car. *Mud-guards*, or *fenders, j* are placed over the wheels and connected together on each side of the car by a footboard, or *running board, k*.

The part *l* of the body, just in front of the driver, is called the *cowl*. In front of the cowl is a metal *hood m* that covers the engine. In some old cars the engine is located under the body of the car, and the gasoline tank or electric battery is placed under the hood.

Doors *n* give access to the body, and a top, of which the top cover *o* is shown, the top being folded up, is usually provided for protection.

TYPES OF AUTOMOBILE WHEELS

Classification.—Most automobiles are equipped with *wooden wheels* of the so-called *artillery type*, a form of wheel used on gun carriages and one capable of withstanding severe shocks under heavy loads. Early types of automobiles were equipped with *wire wheels*; that is, wheels having wire spokes. Such wheels are again coming into use on account of the progress made in wire-wheel construction. Wooden wheels of the artillery type are known as *compression wheels*, because the spokes in the bottom half of the wheel carry the weight and are therefore in compression. Wire wheels are known as *suspension wheels*, because the spokes supporting the hub are in tension, that is, drawn up tightly, and the load may be said to be suspended by these spokes.

Wooden Wheels.—Artillery wheels are usually constructed with the spokes set in a single circle around the hub, between the flanges of which they are securely clamped by means of

bolts. As compared with wire wheels, this type of wheel is more easily cleaned, is more elastic, and is not subject to deterioration on account of rusting. Ordinarily, the spokes lie in a plane perpendicular to the longitudinal center line of the hub, but in a few cases they are *dished*; that is, they are set inwards at the hub and are not perpendicular to the center line of the hub. The dished construction is claimed by some manufacturers to give the wheel greater strength to resist lateral or sidewise stresses, as when turning corners. In some

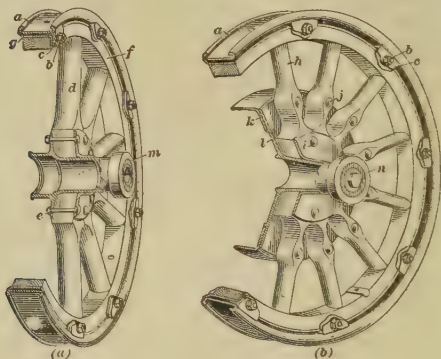


FIG. 2

automobiles equipped with wooden wheels, each front wheel has ten spokes and each rear wheel, twelve; although, in most cases, both front and rear wheels are provided with either ten or twelve spokes each.

The construction of a typical wooden automobile wheel is shown in Fig. 2, which illustrates the front and rear wheels used on some models of the Packard car. Part of each wheel is cut away in order to show the arrangement of the parts at the hub. Except for the different number of spokes and the different requirements at the hubs, the construction of the two wheels is

identical. As shown, they are fitted with demountable rims *a*, which can be taken off quickly by removing the nuts *b* and the cleats *c*. The front wheel, which is illustrated in view (a), contains ten spokes *d* set around the hub in a single circle and held in place by bolts *e* that pass through the hub flanges. The felloe *f* and the spokes are bound in place by the steel felloe band *g*, which is pressed over the felloe.

In view (b) is shown the rear wheel, which contains twelve spokes *h* arranged in a single circle, like the spokes in the front wheel. These spokes are held in place by bolts *i* that pass through the hub flanges and bolts *j* that are used for attaching the brake drum *k*. The bolts *j* pass through the brake drum *k*, the hub flange *l*, and the spokes, thus tying, or binding, these parts together. Part of the hole in the hub is squared in order that the wheel may be driven by the squared end of the axle shaft; other means of driving the rear wheels are widely used.

The hub caps *m* and *n* are provided to keep dust and dirt out of the hubs and to give the hubs a finished appearance.

Wire Wheels.—The general appearance of a typical wire wheel is clearly shown in Fig. 1. Automobile wire wheels are constructed on practically the same principle as ordinary bicycle wheels. Usually, the spokes are arranged about the hub in three circles, the spokes being attached to the inner hub flange and the outer hub flange. All the spokes are tightened to exactly the same tension, so that they hold the hub in a central position and equalize the strain on the hub and the rim. The principal advantages claimed for wire wheels over wooden wheels are that they are stronger and will withstand a greater driving stress in proportion to their weight. It is also claimed that wire wheels keep cooler than wooden wheels, on account of their ability to radiate heat more readily, and hence the tires are not affected to so great an extent by the heat generated when rotating rapidly.

Wire wheels are seldom fitted with demountable rims. It is the common practice, however, to construct wire wheels so that the whole wheel, in case of tire trouble, can be quickly detached from a hub that remains in place. A spare wheel carrying a fully inflated tire is then slipped on in place of the wheel carrying the injured tire.

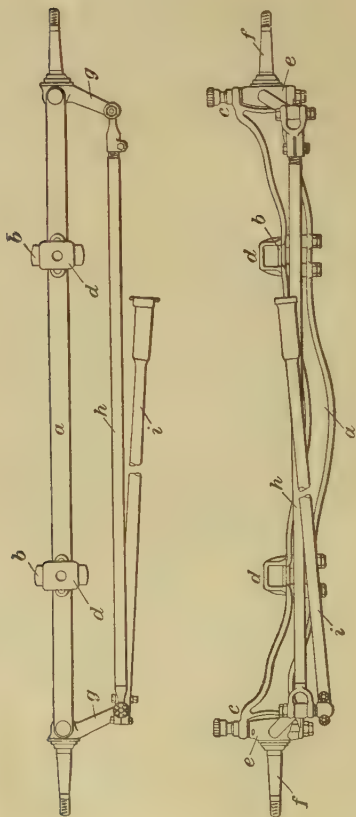


FIG. 3

Some wire wheels, chiefly for use with low-priced cars, have no provision made for quickly detaching the whole wheel.

Comparatively few American automobiles have wire wheels as standard equipment, but for many cars such wheels are listed as an option instead of artillery wheels.

Wire wheel rims, like those of artillery wheels, are made for regular soft-bead clincher tires, for quick-detachable clincher tires, and for quick-detachable straight-side tires.

FRONT AXLES

The *front axle assembly* of an automobile is made up of four parts: a bar carrying the spring seats, two knuckles carrying the spindles on which the wheels turn, and a cross-rod by which the two knuckles are tied together so as to move in unison. Practically all modern automobiles use solid front axles, by which is meant that the bar carrying the spring seats and the yokes to which the knuckles are pivoted, are forged in one piece.

A plan view and rear view of a typical solid front axle assembly are shown in Fig. 3. This consists of the front axle *a* having an I beam section and having the two spring seats *b* as well as the two yokes *c* formed integral with it. Spring clips *d* serve to attach the springs to the axle. The two steering knuckles *e* that carry the wheel spindles *f* are each pivoted by a long pin to the yokes. Each knuckle has an arm *g*, each of which is connected by a cross-rod *h* that forces the two knuckles to turn in unison. The rod *i* connects to the steering gear.

When steering knuckles are placed between the jaws of the axle yokes, they are said to be *Elliot steering knuckles*; sometimes the axle is formed without yokes, the latter being placed on the steering knuckles, which are then called *reversed Elliot steering knuckles*. In another design the axle is without yokes; each steering knuckle carries a vertical pin that passes through a vertical hole in each axle end. The steering knuckles are sometimes mounted below the axle ends, and are spoken of as *Lemoine steering knuckles*. If the steering knuckles are mounted above the axle ends, they are called *reversed Lemoine steering knuckles*.

Tubular front axles, in which the ends receiving the steering knuckles, and also the spring seats, are separate castings or forgings, pinned and brazed to a seamless steel tube, were extensively used at one time, and are still used on some cars.

REAR AXLES

Types of Rear Axles.—A *live axle* is one that not only takes its proportionate part of the weight of the car and the occupants but at the same time serves to drive the rear wheels and thus propel the vehicle. A *dead axle* is one that has no rotating parts, the wheels being driven by side chains from a countershaft, of which the differential forms a part. There are two kinds of live axles, namely, the *chain-drive rear axle* and the *shaft-drive rear axle*. Live rear axles may also be classified as *plain*, *semi-floating*, *three-quarter floating*, and *full floating*. They are made up of three principal parts, namely, a *two-piece driving axle shaft*, a *differential*, and a *housing*.

Chain-Driven, Live, Rear Axle.—The earliest form of live rear axle was driven by chain; it is today entirely obsolete, being found only on very old cars.

Shaft-Driven Rear Axles.—The terms *plain*, *semi-floating*, *three-quarter floating*, and *full floating*, when used in connection with rear axles, refer not to the method of propelling the rear wheels, but to the arrangement of the axle-shaft bearings and the method of driving the rear wheels by the axle shaft. Shaft-driven rear axles are divided into two general classes according to the means employed for driving the axle shaft; these classes are the *bevel-gear driven* and the *worm-gear driven*. Bevel-gear driven rear axles, in accordance with the kind of tooth used in the bevel gears, are divided into *straight-tooth* and *helical-tooth*, the latter also being called *worm-bevel-tooth*, bevel-gear rear axles.

The most widely used example of a plain rear axle is the one used in the Model T Ford car; this is shown in Fig. 4, (a) being an external view and (b) a sectional view. The two views are lettered the same, but are drawn to different scales. The axle housing *a* is made in two halves bolted together at the center; the axle shaft consists of two parts *b*, *b'*, which are brought together at the differential *c*, the gear *d* being keyed to the

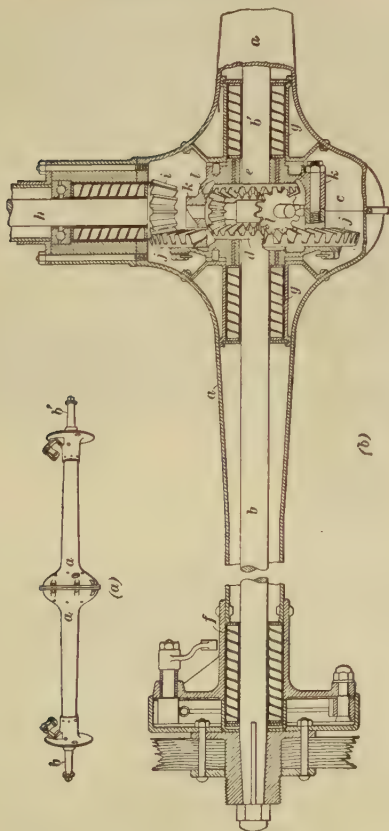


FIG. 4

end of *b* and the gear *e* to the end of *b'*. Each part of the shaft is supported by two roller bearings *f* and *g*. The road wheels are keyed to the outer ends of the axle shaft, which is tapered at these ends, as shown. The axle is driven from the engine through the propeller shaft *h*, which drives the differential, and, consequently, the axle shaft and road wheels, through the bevel pinion *i* and the large bevel driving gear *j*.

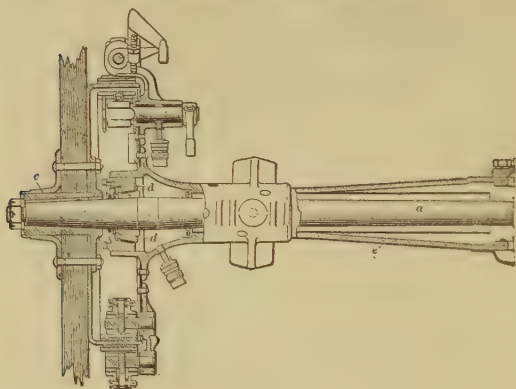


FIG. 5

It will be noticed that the differential has its bearings on, that is, is supported by, the two halves of the axle shaft; this constitutes the difference from the semi-floating axle, where the differential is supported by bearings attached to the axle housing.

Fig. 5 shows in section a semi-floating rear axle as used in many medium-priced cars. Each half of the axle shaft *a* is splined at its inner end and fits in a gear forming part of the differential. To the outer end of the axle shaft the hub *c* of the rear wheel is keyed, or otherwise fastened. Each half of the axle shaft runs in bearings *d*, the one being formed in the

center of the differential casing and the other on the inside of the outer end of the axle tube *e*; the outer bearings prevent the axle halves from coming out. The weight of the car is carried directly on the axle shafts *a*, which hence are subjected to a torsional and bending stress when the engine is driving the car.

Fig. 6 shows a three-quarter floating rear axle in section. Each half of the axle shaft *a* is driven from its own gear of the differential, the end of the axle shaft being squared or splined. A cap or flange *b* is keyed, or otherwise fastened, to the outer end of the axle shaft; in some designs, the flange is integral with

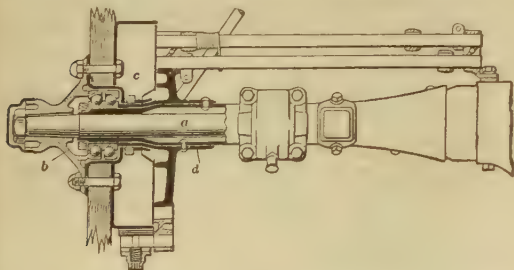


FIG. 6

the shaft. The wheel hub *c* carries on its inside, and closely in line with the center of the spokes, antifriction bearings, which are annular ball bearings in this case. The inner races of the bearings are placed on the outside of the axle tube *d*. The flange *b* is rigidly bolted to the wheel hub *c*. Owing to the construction, the weight of the car is carried on the axle tube and none on the axle shaft, which is subjected chiefly to a torsional stress, but also sustains slight bending stresses owing to its rigid attachment to the wheel hub. The wheel resists side stresses through the resistance of the axle shaft to bending.

In Fig. 7 is shown, in section, a full-floating, live, rear axle, which somewhat resembles the three-quarter floating axle. The wheel hub is supported by two bearings *a* and *b* placed outside the axle tubing. The two bearings not only support

the wheel in a vertical plane, but also take care of all side stresses coming on the wheel. Each axle shaft *c* is splined at the outer end, and floats in the driving flange *d* bolted to the rear wheel hub *e*. The axle shaft drives the wheel through this flange. In consequence, the axle shaft is only subjected to torsional stresses. In some cases the rear wheel is driven by a jaw clutch instead of a flange.

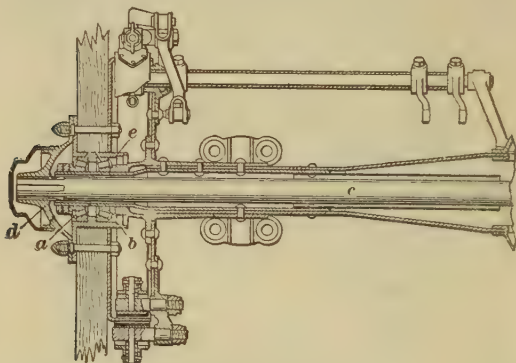


FIG. 7

In most three-quarter floating and all full-floating axles, the axle shafts can be withdrawn from the axle housing without removing the wheels from it; in axles of the semi-floating type the removal of the axle shafts necessitates removing of the wheels and taking apart of the axle housing.

TORQUE ARMS AND RADIUS RODS

Torque Arms.—The rear axle of a car has a tendency to rotate in a direction opposite that in which the wheels are rotating when the engine is driving the car. The turning effort tending to rotate the axle is equal to that which drives the traction wheels. When the clutch is thrown out and the hub

brakes are applied, the wheels tend to drag the axle around with them. The turning effort then acting on the axle is equal to that resisting the rotation of the road wheels. This applies to both shaft drives and chain drives, whether the latter are of the single, or center, chain type, or of the double, or side, chain type. Unless some other means is provided, the springs of the car and their connections to the axle prevent the axle from rotating.

Some cars are fitted with a *torque arm* of some kind to prevent rotation of the rear axle. In many cars, the torque is taken care of by a tube surrounding the propeller shaft, the tube being bolted to the rear-axle housing and carrying a bearing for the propeller shaft at its forward end. Some torque tubes do not carry a propeller-shaft bearing, but are supported

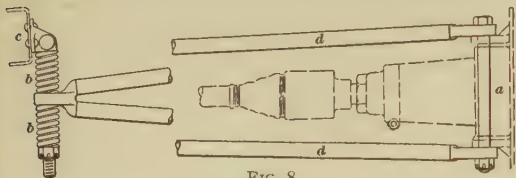


FIG. 8

at their forward end by a cross-member of the frame. When a torque tube is used, the propeller shaft carries a single universal joint at its forward end.

When it is considered desirable to have two universal joints on the propeller shaft, a torque member similar to that shown in Fig. 8 is rigidly bolted to the rear axle housing *a*; its forward end is mounted between two stiff helical springs *b*, which in turn are supported on a stud hinged to a frame cross-member *c*. The torque member in the case shown is made of two rods *d*, joined to suitable fittings at their front and rear ends. Mounting the forward end of the torsion member between springs greatly relieves the stresses coming on the cross-member *c*. In many cases the torque arm is pressed from steel plate.

Some engineers attach the forward end of the torsion member to the frame cross-member by a swinging link.

Radius Rods.—In order to keep the rear axle always at right angles to the frame, *radius rods* are used. These rods, one on each side of the frame of the car, are usually provided with two yoke ends, one of which is pinned to a lug carried by the spring-seat forging or by a special fitting on the axle tube, and the other to a lug on the frame, permitting the axle to move freely up and down, but maintaining equal distances to the ends of the axle.

Radius rods must be used in connection with springs parallel to the frame and shackled to links at both ends, irrespective of whether half-elliptic, three-quarter-elliptic, full-elliptic, or platform springs are used. In these cases the radius rods also take the driving strain. When full-elliptic springs without shackles, or half-elliptic springs with one end hinged to the frame and the other end shackled, or an equivalent spring construction, are used, radius rods are not needed.

With front axles and rear axles attached to the frame by a single cross-spring, radius rods are needed.

AUTOMOBILE CHAINS

There are three common types of automobile chains, known as the *block chain*, the *roller chain*, and the *silent chain*. As shown in Fig. 9, one type of a detachable *block chain* consists of steel blocks *a* held by pins *b* between hardened side links *c*,



FIG. 9

the distance from center to center of the links being called the *pitch* of the chain. The pins of this chain permit of detaching the chain at any link. The

pin is flattened where it draws into a slot that is somewhat smaller than the diameter of the openings *d* in the side links through which the pins are introduced. In other forms of block chains the links are not detachable, the pins being riveted fast to the links. With such non-detachable chains, the final connection is made by a special detachable link furnished by the chain manufacturer, and called a *master link*.

Fig. 10 illustrates one form of a chain, known as the Baldwin detachable roller chain, the construction being such as to per-

mit detaching the chain at any link. It consists of pins *a* that carry rollers *b*, which rotate on bushings *c* that surround and turn on the pins *a*. Near the end of each of the two pins of the master link are milled two slots *d*, into which, after the side link *e* is slipped on, the clips, or fasteners, *f* are forced and



FIG. 10

closed by a pair of pliers. These clips may be removed by means of a screwdriver or with a special tool provided by the chain manufacturer. The pins or studs are knurled at the neck where they pass through the links, into which they are forced under pressure. Other forms of roller chains are not detachable, final connections being made by a master link.

Sprocket wheels for block chains are shaped entirely different from those made for roller chains, as comparison of Figs. 11 and 12 shows. Consequently, roller chains cannot be replaced by block chains, or vice versa, without changing sprocket wheels as well. There is an exception to this statement, however; one manufacturer has recently placed a roller chain on the market under the name of Brampton's Duplex roller chain, which in the pitches and widths in which it is made, fits block-chain sprocket wheels. When designating the width of chains, the inside measurement is used; that is, in



FIG. 11

the block chain, the width of the block; and in the roller chain, the width of the roller.

The third form of chain is the silent chain, of which the form known as the Link-Belt silent chain, made by the Link-Belt Company,



FIG. 12

Philadelphia, Pa., is shown in Fig. 13. It is made up of stamped steel links *a* mounted on two-piece bushings *b*, through which are passed shouldered steel pins *c*. Opposite the shouldered ends of the pins are washers that hold the link pins in place. The two-piece bushings *b* are prevented from

turning entirely around by inwardly extending projections on the links *a*. A special form of sprocket wheel is needed with the silent chain, the wheels being usually flanged to confine the chain sidewise. It is a peculiarity of the silent chain that wear of the chain and sprocket wheels does not destroy the accuracy of the fit between them, differing in this respect from block and roller chains, where the slightest wear destroys the fit between the chain and the sprocket, throwing all the load on one sprocket tooth.

It is possible to replace the pins and bushings of the Link-Belt silent chain with new ones after these parts are worn,

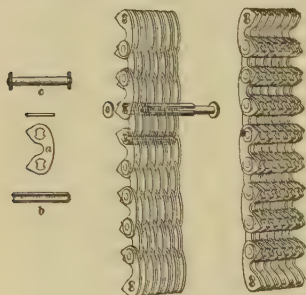


FIG. 13

thus bringing the chain back to its correct pitch and length. Also, if the sprockets are symmetrical in regard to the length of their hubs, it is possible to reverse the sprockets, thereby presenting new surfaces to the links. Furthermore, the Link-Belt silent chain can be reversed in case the links and sprockets are badly worn on one side, thereby securing practically a new drive.

Some silent chains on the market cannot be repaired when worn, and some will only run in one direction and therefore cannot be reversed; most makes of silent chain will run equally well in both directions, however.

With all silent chains it is perfectly feasible to use new chains or repaired chains over the old sprockets, unless these are completely worn out. With block chains and roller chains, however, when either a chain or a sprocket is worn enough to need replacing, both sprocket wheels and the chain should be replaced; new chains will not fit old sprockets, nor will new sprockets fit old chains.



FIG. 14

Silent chains are extensively used in connection with gasoline engines, for driving cam-shafts, magnetos, water pumps, generators, starting motors, etc.

To compensate for the wear of chains and sprockets, and thus to keep the chain tight, the center-to-center distance of the sprockets is often made adjustable, or an adjustable idler is provided. When neither adjustment nor idler is provided, as is the case in many automobile engines, replacement of the chain drive is the only possible cure for slackness of the chain due to wear.

AUTOMOBILE SPRINGS

Automobiles are equipped with various types of springs, examples of which are presented in Fig. 14. All are made up of long comparatively thin and narrow curved steel plates, laminations, or *leaves*, of different lengths. The leaves are usually held together by a bolt at the center, and the shorter ones are prevented from moving sidewise by small lips at their ends, by projections of one leaf entering corresponding depressions of the next leaf, or by clips that pass around them. In many automobile springs the center bolt is eliminated, the leaves being held together by the spring clips, and shifting of the leaves being prevented by various means. The springs minimize the effect of road shocks on the occupants of the car, as well as on the machinery.

There are three types of *full-elliptic spring*; (a) shows the common *button-head type*, (b) the *single-scroll type*, and (c) the *double-scroll type*. The upper and lower halves of the spring are held together by bolts or pins passing through eyes or through links at the ends of the spring. In (d) is shown the much used and very popular *three-quarter-elliptic spring*, which may be said to represent a cross between the full-elliptic spring and the more frequently used *half-elliptic spring* (e). A specially constructed half-elliptic spring, known as the *Titanic spring*, which does not have a bolt at the center, is shown in view (f). The leaves of this spring are arched so as to form a hump at the middle, and are clamped over a filler that maintains this hump. A *cross-spring* is a spring that runs crosswise on the car, and therein it differs from the springs previously described, which are arranged lengthwise with the frame. The cross-spring

resembles an inverted semielliptic spring, as will be seen on referring to (g), which shows the rear cross-spring of the model T Ford car. When in place on the car, it is shackled to lugs on the axle at both ends and supports the load at its center.

In (h) is shown a *platform spring*, of which the side members are half-elliptic springs shackled to the cross-member, and the rear member is an inverted half-elliptic spring. This spring assembly is used as a rear spring, and it is attached to the frame at the forward ends of the side members and at the center of the cross-spring.

A *floating cantilever spring* is shown in (i). It consists of an inverted and very flat semielliptic spring shackled at its rear end to the rear axle and at its front end to the frame, and pivoted at its middle to the frame. The spring may also be attached to the axle by means of a roller connection, which allows a free backward-and-forward motion. When supported in this manner, it extends underneath the axle. A *plain cantilever spring* consists of a quarter-elliptic spring, having its big end rigidly attached to the frame and its small end shackled or otherwise attached to the axle.

After a spring has been compressed, the following upward movement, or *recoil*, tends to cause separation of its leaves, which separation may result in their breakage. This fact is especially true of the master leaf. To reduce this danger of spring breakage through recoil, many springs are now fitted with *recoil clips*, which are narrow clips that surround several spring leaves and the master leaf, and that permit free sliding of the leaves on each other while restraining their separation. Such recoil clips are shown at *a* in Fig. 14 (c), (d), (f), (g), and (h).

FRAMES

There are two types of frames for automobiles, namely, the *armored-wood frame*, which consists of wooden sills strengthened by steel plates, and the *pressed-steel frame*. The latter is made of steel parts pressed to shape in dies in large hydraulic presses. The wood frame is at present only used by one manufacturer, who laminates the wood, and claims that the wood more satisfactorily dampens vibrations than a steel frame.

Pressed-steel frames are used almost exclusively today. They are composed, broadly speaking, of two side members of channel section and a number of cross-members attached to the side members by riveting. The side members viewed from above, may be straight, or offset inwardly in front. The offsetting permits a greater steering angle than ordinarily is obtained with straight side members, using the same width of body.

Side members, if viewed from the side, may be straight on top, or they may be offset upwards at the rear; when thus made the frame is called a *kick-up frame*. When offset upwards both in the front and rear, the frame is called a *double kick-up frame*. The object of a kick-up is to bring the car body lower to the ground than can be done otherwise with a frame carried above the axles. When a frame is carried below the axle, it is called an *underslung frame*. Many pressed-steel frames are narrowed at the front end in order to give a larger turning arc to the front wheels of the car; such a frame is said to be *inswept*. The same effect as insweeping is gained by bringing straight side members of the frame closer in the front than at the rear; this practice is followed by many car makers.

Some models of cars have been fitted with *subframes*, that is, auxiliary frames for the purpose of supporting the engine and the speed-change gear. These frames are built into the main frame, and consist of two longitudinal members located immediately inside of the main side rails, and running from the front cross-member to an intermediate cross-member. The engine and the transmission case are mounted on these longitudinal members. Like the main frame, the subframe is generally made of pressed-steel shapes of channel cross-section, although tubular subframe members are sometimes found.

LAYOUTS OF CHASSIS

In shaft-driven cars, there are several different methods of arranging the engine, transmission, and rear axle in reference to each other; the most common ones are shown in Fig. 15. It will be understood that the clutch is included with the engine, even though it may be placed inside the transmission housing. In the first method, the engine and transmission are combined into a unit; a propeller shaft enclosed in a torque tube is used,

and joined to the transmission by a single fully enclosed universal joint. This is shown in view (a).

A unit power plant is employed in the method shown in (b). The clutch is next to the engine, and is enclosed in the same casing with the transmission. The propeller shaft is not housed, and a flexible connection between the rear axle and the transmission is made by means of two universal joints, one at each end of the propeller shaft. Rotation of the rear axle housing in either direction is prevented by a torque arm.

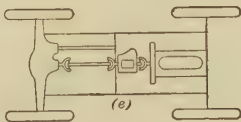
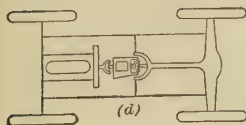
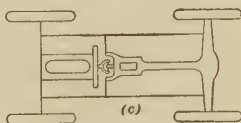
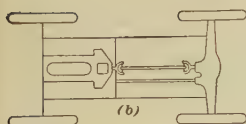
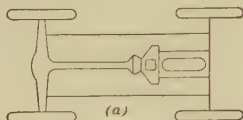


FIG. 15

In the method shown at (c), the engine and clutch form a unit, and the transmission is in a separate casing mounted on the end of the propeller shaft housing. The propeller shaft housing is rigidly bolted to the rear axle housing, making the rear axle housing and transmission in permanent alinement. The propeller shaft, therefore, has no universal joints. The power of the engine is transmitted to the transmission through a short driving shaft having one or two universal joints.

In view (*d*) is shown a fourth method. Here the engine is connected to a separate transmission by a single universal joint. The transmission is connected to the propeller shaft by a single universal joint; the shaft is enclosed in a torque tube.

Another method is shown in (*e*). Here the engine is connected to a separate transmission by a single universal joint; the transmission is connected to the rear axle by a propeller shaft having a universal joint at each end. A separate torque arm or an equivalent thereof must be employed with this construction.

The several methods of arranging the engine, transmission, and rear axle that are here given apply equally well to one-cylinder, two-cylinder, four-cylinder, six-cylinder, eight-cylinder, and twelve-cylinder engines, as all modern passenger cars have the engine in front.

In many cars, no radius rods or torque members are used. The top leaf of the lower rear spring is made heavy enough to confine the rear axle to its proper place and prevent rotation of the axle housing. This method of holding the rear axle and also driving through the springs is known as the *Hotchkiss drive*, and applies to semielliptic, cantilever, and full-elliptic springs. In order for a Hotchkiss drive to be used successfully, it is necessary that the springs be hinged at their forward ends to the frame of the car, and that they be fastened rigidly at the middle to the rear axle housing.

BODIES

Sixteen forms of bodies are shown in Figs. 16 and 17, their names and definitions being those officially adopted by the Society of Automotive Engineers.

In Fig. 16 (*a*) is shown a *roadster*. Definition: An open car seating two or three. It may have additional seats on running boards or in rear deck.

In view (*b*) a *coupélet* is shown. Definition: Seats two or three. It has a folding top and full-height doors with disappearing panels of glass.

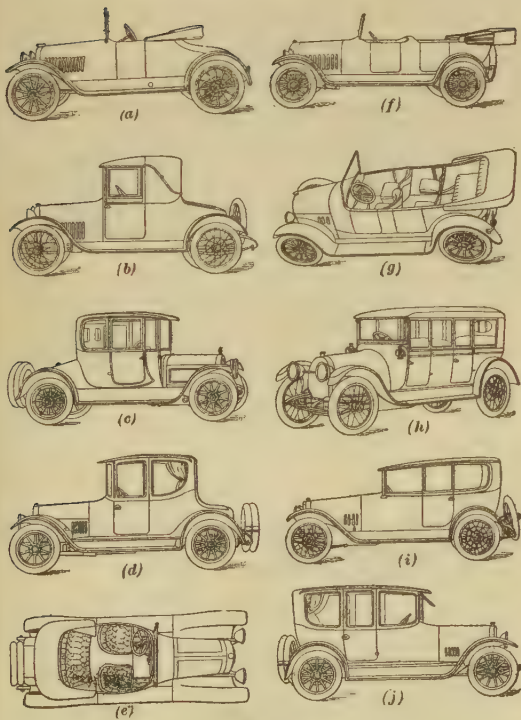


FIG. 16

In (c) a *coupé* is shown. Definition: An inside operated enclosed car seating two or three. A fourth seat facing backwards is sometimes added.

In (d) a *convertible coupé* is shown. Definition: A roadster provided with a detachable coupé top.

In (e) the *clover leaf* design of a body is shown. Definition: An open car seating three or four. The rear seat is close to the divided front seat and entrance is only through doors in front of the front seat.

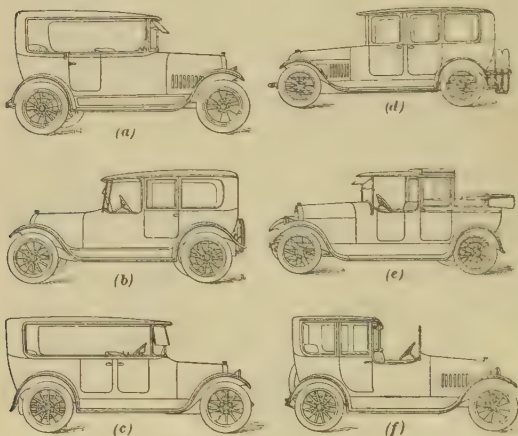


FIG. 17

In (f) the *touring car* is shown. Definition: An open car seating four or more with direct entrance to tonneau and to undivided front seat.

In (g) is shown the *salon touring car*. Definition: A touring car with passage between the two front seats, with or without separate entrance to front seats. The salon touring car, like the touring car, is always fitted with a folding top.

In (h) the *convertible touring car* is shown. Definition: A touring car with folding top and disappearing or removable glass sides.

In (i) a *sedan* is shown. Definition: A closed car seating four or more, all in one compartment.

In (j) a *convertible sedan* is shown. Definition: A salon touring car provided with a detachable sedan top.

In Fig. 17 (a) an *open sedan* is shown. Definition: A sedan so constructed that the sides can be removed or stowed so as to leave the space entirely clear from the glass front to the back.

In (b) a *limousine* is shown. Definition: A closed car seating three to five inside, with the driver's seat outside, covered with a roof.

In (c) is shown an *open limousine*. Definition: A touring car with permanent standing top and disappearing or removable glass sides. May or may not have a partition between the driver and the passengers. The front seat is not divided.

In (d) a *berline* is shown. Definition: A limousine having the driver's seat entirely enclosed.

In (e) a *landaulet* is shown. Definition: A closed car with folding top, seats for three or more inside, and driver's seat outside.

In (f) a *brougham* is shown. Definition: A limousine with no roof over the driver's seat.

GASOLINE AUTOMOBILE ENGINES

DEFINITIONS

An *internal-combustion engine* is one in which a combustible mixture of air and gas is ignited and burned within the engine cylinder. The burning of the fuel results in the production of gases of high temperature and pressure, which act directly on a piston that moves back and forth in a cylinder. In automobile engines, work is done on one side of the piston only; such engines are known as *single-acting engines*.

The *charge* is a mixture of fuel and air taken in at one stroke of the engine. The *exhaust gases*, sometimes called the

exhaust, are the waste products of combustion that are expelled from the engine. The *compression space* includes the entire space between the piston face and valves when the piston is in its position nearest the cylinder head. It is sometimes called the *clearance*, or *combustion, space*.

Internal-combustion engines as used in automobiles operate on either the *four-stroke cycle* or the *two-stroke cycle*. By this is meant that one complete cycle of operation is concluded either in four piston strokes or in two piston strokes. A complete cycle consists of the admission of the fresh charge, the compression of the fresh charge, the explosion or burning of the fresh charge, and the exhaust of the burnt gas.

ARRANGEMENT OF ENGINE PARTS

A sectional view of a four-cycle poppet-valve gasoline engine such as is used on automobiles, is here shown in Fig. 1. At *a* is shown the cylinder; at *b*, the cylinder head; at *c*, the piston; at *d*, the piston pin, or wristpin; at *e*, the crank-shaft; at *f*, the crank; at *f*₁, the crankpin; at *g*, the connecting-rod; at *h*, the inlet, or admission, port through which the combustible charge enters the cylinder; at *i*, the passage through which the charge flows into the port *h*; at *j*, the inlet, or admission, valve, approximately disk-shaped, which closes the inlet passage at the proper time; at *j*₁, the valve seat in which the valve *j* rests when closed; at *k*, the inlet-valve stem, rigidly attached to and forming part of the valve *j*; at *l*, a coiled compression spring that holds the valve *j* closed, except at such times as it is forcibly opened to admit a charge to the cylinder; at *m*, the lifting rod, push rod, or thrust rod, that lifts the valve *j*; and at *n*, the inlet cam rigidly attached to the inlet cam-shaft *o*, also called the *half-speed shaft*, or *lay shaft*. As the inlet cam *n* rotates, its projection, or lobe, bears against the roller at the lower end of the push rod *m* and lifts the rod, which in turn lifts the inlet valve *j*. The burned gases escape from the cylinder through the exhaust port *p* into the passage *q* and thence to the atmosphere. The exhaust valve *r* closes the exhaust passage except at such times as it is forcibly opened to release the burned gases. At *s* is shown the exhaust-valve stem; at *t*, the exhaust-valve closure spring; at *u*, the exhaust-valve

push rod; at v , the exhaust-valve cam; at w , the exhaust-valve cam-shaft; at x , a compression relief cock, or petcock, with funnel top; at y , the spark plug; at z , the space for cooling water, which forms a water-jacket to keep the cylinder and adjacent parts from becoming too hot; at a_1 , valve-stem guides; at b_1 , push-rod guides; and at c_1 , the crank case.

OPERATION OF FOUR-CYCLE ENGINE

The operation of the four-cycle type of automobile engine is as follows, starting with the piston in its position nearest the cylinder head and the space between the piston and valves filled with air or burned gases at atmospheric pressure:

First Stroke.—The piston moves downwards on the first out stroke and the inlet valve is forcibly opened at this time. The suction in the cylinder draws combustible mixture into the cylinder during the complete outward stroke. The exhaust valve is kept closed during this stroke. The inlet valve closes by the action of its spring shortly after the completion of the outward stroke of the piston. This movement of the piston is variously known as the *charging*, *admission*, *inlet*, *suction*, and *induction stroke*.

Second Stroke.—The piston moves upwards and compresses the charge into the space a , Fig. 1, above the piston. Both valves remain closed during this compression stroke. The charge is ignited by an electric current that is passed through the spark plug at about the time that the compression stroke is completed.

Third Stroke.—The pressure against the piston face drives it outwards again on a second outward stroke called the *working*, *impulse*, *explosion*, or *combustion stroke*. Both valves remain closed from the beginning to nearly the end of the impulse stroke. The exhaust valve is opened mechanically just before the completion of the stroke, and part of the burned gases escapes into the atmosphere, so that the pressure in the cylinder falls nearly as low as that of the atmosphere. The exhaust valve is opened against the resistance of both its closing spring and the gas pressure in the cylinder. This opening of the exhaust valve is accomplished by the action of the cam v during its rotation, which is at half the speed of that of the crank-shaft.

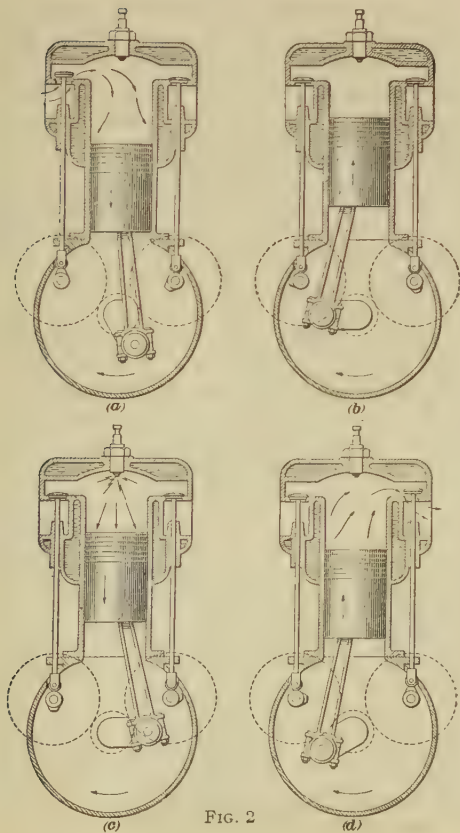


FIG. 2

Fourth Stroke.—The piston, driven by the crank-shaft, moves upwards on a second inward stroke and expels part of the burned gases from the cylinder. This is generally known as the *exhaust stroke*—less commonly, as the *eduction*, or *ejection*, *stroke*. The space *a* that forms the combustion chamber remains filled with the burned gases at the completion of the exhaust stroke. The completion of the exhaust stroke ends the cycle of operations, which are repeated again and again.

The various steps in the operation of the four-cycle type of automobile engine and the corresponding positions of the valves are illustrated in Fig. 2. In (*a*) is shown the suction stroke, with the inlet valve open; in (*b*), the compression stroke, with both valves closed; in (*c*), the impulse stroke, with both valves still closed; and in (*d*), the exhaust stroke, with the exhaust valve open.

One-cylinder, two-cylinder, and three-cylinder engines were used at one time for automobile work, but are now obsolete.

FOUR-CYCLE ENGINE CYLINDER ARRANGEMENT

Number of Cylinders.—The typical automobile engine has from four to twelve cylinders, is small and compact, is of light weight, and is run at high speeds, sometimes as high as 3,500 revolutions per minute. An automobile engine is controlled entirely by hand throttling of the ingoing charge (this includes use of the accelerator), and automatic and also hand variation of the time of ignition. The charge is ignited by an electric spark caused to pass between the electrodes of the spark plug, which is screwed into the cylinder so that the electrodes reach into the combustion chamber.

Four-Cylinder Engines.—In a four-cylinder four-cycle engine of the vertical type, all the cylinders are generally located on one side of the crank-shaft, with all their axes in the same plane, as shown in Fig. 3, which is a diagrammatic illustration. Three bearings *a*, *b*, and *c* support the crank-shaft. The cranks of the two end pistons are at an angle of 180° with those of the two middle pistons. The end pistons therefore move in unison and in a direction opposite to the motion of the two middle pistons. The power impulses occur every half revolution in a four-cylinder four-cycle engine thus arranged. The impulses

in the end pair of cylinders alternate with those of the middle pair.

The *order of explosions*, referring to the numbers in the cylinders, Fig. 3, may therefore be either 1-3-4-2 or 1-2-4-3. If the order of the impulses is 1-2-4-3, and cylinder 1 is on the impulse stroke, 2 is compressing, 3 is exhausting, and 4 is drawing in a fresh charge. As the two middle pistons move in unison and in a direction opposite from that of the two end pistons, the whole system of moving parts is well balanced. There is practically no tendency for the moving parts to twist the crank around sidewise.

Six-Cylinder Engines.

Six-cylinder, four-cycle, vertical engines are much the same in form as the usual type of four-cylinder engines. The six cylinders are placed in a row above the crank-shaft. The cranks may be considered as being in pairs, the cranks of a pair having no angle between them; that is, both are on the same side of the crank-shaft

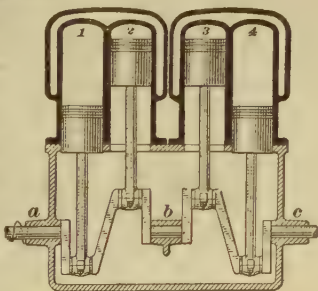


FIG. 3

and in the same plane. The two cranks of a pair may be either adjacent to each other or separated by other cranks interposed between them. The three pairs of cranks are at an angle of 120° with one another, corresponding to one-third of a revolution.

The impulses occur at intervals of one-third of a revolution; therefore, there are three impulses per revolution. The usual arrangement of the cranks is as follows: the cranks for the first and sixth cylinders are in line; the cranks for the second and fifth cylinders are in line; the cranks for the third and fourth cylinders are in line. By this arrangement there is no tendency to turn the shaft sidewise on account of lack of balancing the moving parts. However, other arrangements of cranks on the

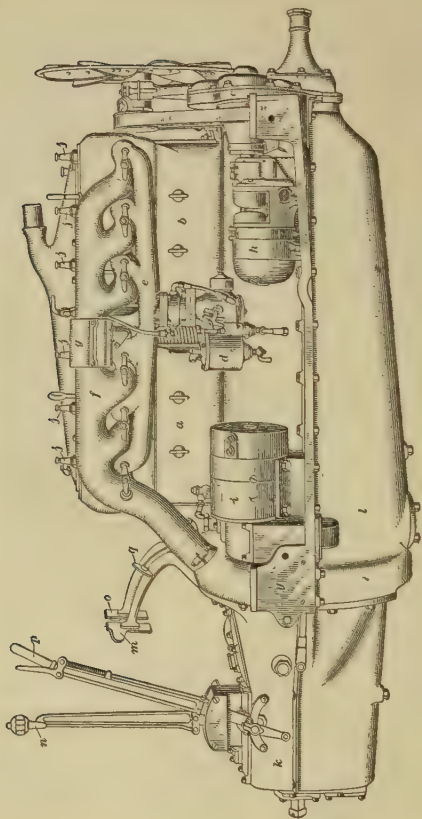


FIG. 4

shaft are possible. For the usual crank arrangement here given, there are eight firing orders: 1-2-3-6-5-4, 1-2-4-6-5-3, 1-5-3-6-2-4, 1-5-4-6-2-3, 1-3-2-6-4-5, 1-3-5-6-4-2, 1-4-5-6-3-2, 1-4-2-6-3-5.

The arrangement of a typical six-cylinder water-cooled automobile engine is shown in Figs. 4 and 5. The same parts have been given the same reference letters in both illustrations, and both should be referred to in reading the description. The two cylinder blocks, the cylinders being cast in blocks of three, are seen at *a* and *b*. The inlet and exhaust valves are located at the right side of the engine (shown in Fig. 4), the valve stems, valve springs, and valve lifters being enclosed. The valves are operated from a single cam-shaft that is driven from the crank-shaft by means of gears contained in the casing *c*. The fuel enters the cylinders from the carbureter *d* by way of the intake manifold *e*, and the exhaust gases escape through the exhaust manifold *f*. At *g* is a sleeve that surrounds the exhaust pipe and is connected to the carbureter for the purpose of supplying warm air to aid in evaporating the gasoline. The dynamo *h* supplies electricity for the electric lights on the car, and the electric starting device *i* automatically cranks the engine when starting. The spark plugs *j* are located over the inlet valves. The clutch and transmission gears are located in the casing *k*, which is rigidly bolted to the engine crank-case *l*, thus forming a unit power plant. The clutch is operated by the foot-pedal *o* and the transmission gears by the hand-lever *n*. The foot-pedal *m* and the hand-lever *p* are for operating the service and emergency brakes, respectively. The foot-pedal *q* is the accelerator pedal, which is used for opening the throttle valve in the carbureter by foot pressure.

The water pump *r* and the magneto *s* are located on the left-hand side of the engine, as shown in Fig. 5. Both are driven by the shaft *t*, which in turn is driven from the crank-shaft through the gears contained in the casing *c*. The water circulation is from the pump *r* through the pipe *u* to each casting, thence to the radiator by way of the connection *v*, and back to the pump through a pipe not shown. The breather pipe *w* allows the escape of hot gases from the crank-case and affords a means of pouring oil into the oil reservoir in the

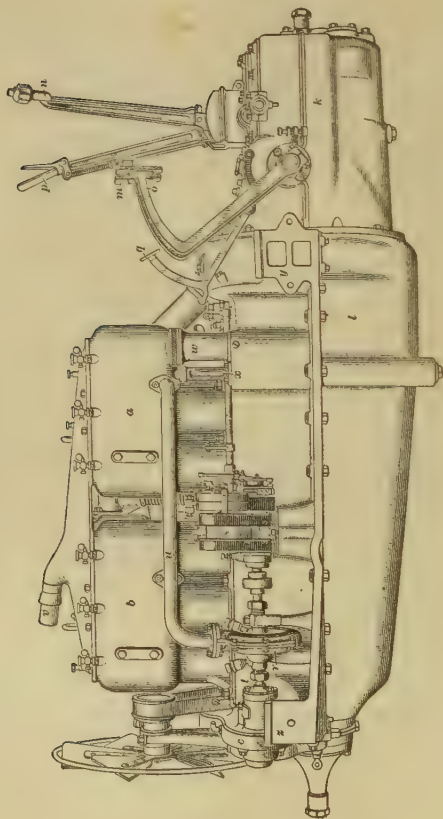


FIG. 5

bottom of the crank-case. An oil-level gauge is located at *x*. The power plant is supported in the frame of the car by the four arms *y* and *z*, two on each side.

The air-cooled six-cylinder engine used in the Franklin car is shown in Fig. 6. The distinguishing feature of this engine is that its cylinders are cooled by means of air-currents flowing over them instead of by means of the usual water-jacket. The cylinders *a* are provided with flanges *b* that increase their radiating surface and make it possible for the cool air flowing around them to carry off enough heat to cool the cylinders sufficiently.

Both the inlet valves and the exhaust valves are located in the cylinder heads, as shown in the first cylinder, in which *c* is the inlet valve and *d* the exhaust valve. The valves are operated from a single cam-shaft *e* by means of push rods enclosed in tubes *f*, and valve rockers. The cam-shaft is driven from the crank-shaft *g* by means of the gears *h* and *i*. An oil pump *j* receives its power from the cam-shaft through a vertical shaft that is driven by helical gears, one of which is seen at *k*. By means of this pump, the lubricating oil is pumped from the reservoir *l* through the lubricating system to the various bearing surfaces. The timer-distributor of the ignition system is mounted on the housing *m*, and is driven from the pump shaft. A plate clutch, enclosed in the fly-wheel *n*, connects the engine crank-shaft with the driving mechanism of the car. The inlet manifold is seen at *o*, but the exhaust manifold is not shown. The crank-shaft *g* is supported by seven bearings, one at each end of the engine and one between each two adjacent cylinders. The valve gear on top of each cylinder is enclosed in an aluminum cover *p*.

Eight-Cylinder Engines.—The form of eight-cylinder engine that is in actual use differs radically from the conventional four-cylinder and six-cylinder automobile engines in that the cylinders are not all in one plane, but are arranged in groups of four in two planes at right angles. This cylinder arrangement makes an eight-cylinder engine but slightly longer than a four-cylinder engine of the same horsepower, and much shorter than a six-cylinder engine of the same horsepower; it also permits of the use of a very simple crank-shaft having four

cranks, arranged just like those of an ordinary four-cylinder engine crank-shaft. A cross-section of an eight-cylinder V-type engine is shown in Fig. 7. As clearly seen, the pistons *a* of each opposite pair of cylinders in the two groups are connected to the same crankpin, there being four crankpins, one of which is shown in section at *b*. The cam-shaft *c* is located above

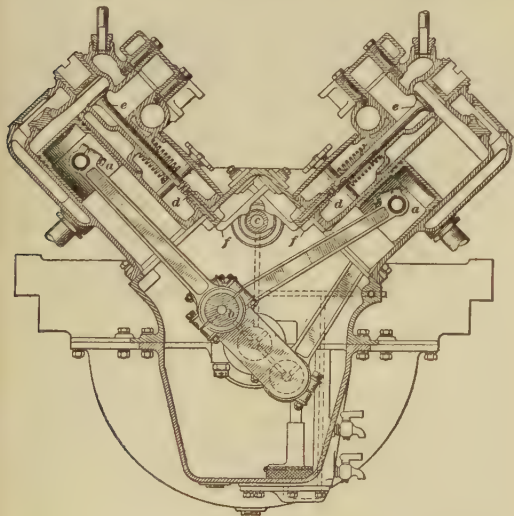


FIG. 7

the crank-shaft, has sixteen cams, and operates the valve lifters *d* and valves *e* by means of rocker-arms *f* that are pivoted at one end. In this case, rocker-arms are used to operate the valve lifters because the cam-shaft could not be located low enough to operate the valve lifters directly and yet have the crank-shaft and connecting-rods clear the cam-shaft.

In considering the firing orders of eight-cylinder **V**-type engines it is well to keep in mind that each group of four cylinders can only have the same two firing orders that any four-cylinder engine can have in order that the explosions may occur 180° apart. These firing orders are 1-2-4-3 and 1-3-4-2, the

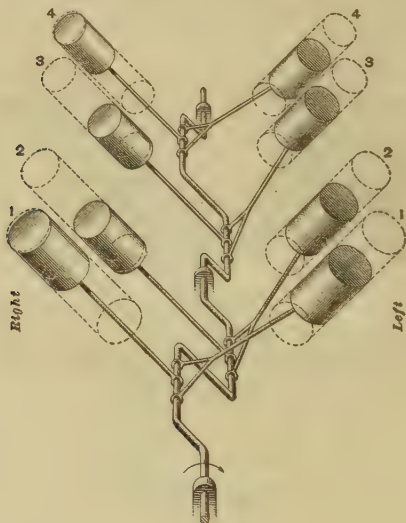


FIG. 8

cylinders, as customary, being numbered beginning at the front end of the car.

In order to prevent any misunderstanding of the firing orders of eight-cylinder **V**-type engines, Fig. 8 is presented. This illustration shows an eight-cylinder **V**-type engine as viewed from the front end of the car. With the crank-shaft

turning clockwise, as shown by the arrow, there are eight possible firing orders, which are

1 right-1 left-2 right-2 left-4 right-4 left-3 right-3 left (1)

1 right-1 left-3 right-3 left-4 right-4 left-2 right-2 left (2)

1 right-4 left-2 right-3 left-4 right-1 left-3 right-2 left (3)

1 right-4 left-3 right-2 left-4 right-1 left-2 right-3 left (4)

1 right-1 left-3 right-2 left-4 right-4 left-2 right-3 left (5)

1 right-1 left-2 right-3 left-4 right-4 left-3 right-2 left (6)

1 right-4 left-2 right-2 left-4 right-1 left-3 right-3 left (7)

1 right-4 left-3 right-3 left-4 right-1 left-2 right-2 left (8)

These eight firing orders are reduced to two, however, when a single cam-shaft with eight cams is used; only the firing orders (3) or (4) can be employed in that case. If two cam-shafts with eight cams on each are used, or a single cam-shaft with sixteen cams is employed, it is possible to use any of the eight firing orders; however, to use either one of the firing orders (5), (6), (7), or (8) means that one group of four cylinders would have a different firing order from the other. Thus, if the right group fires 1-3-4-2, the left group would have to fire 1-2-4-3, etc.

The favorite firing order is that given at (4). This firing order, and also that given under (3), can be easily brought to the mind by remembering that the sum of the numbers of each pair of cylinders which fire in succession is 5. Thus, taking firing order (4), 1 right-4 left=5; 3 right-2 left=5; 4 right-1 left=5; 2 right-3 left=5. The firing order given under (2) is also used.

It is the practice of some builders of eight-cylinder V-type engines to number the cylinders from 1 to 4 on the right side of the car, beginning at the front, and from 5 to 8 on the left side of the car, beginning at the front. With this manner of numbering the cylinders the firing order given under (4) becomes 1-8-3-6-4-5-2-7.

Referring again to Fig. 8, it will be noted that the cranks are in their dead-center position for the right group of cylinders, and that consequently all pistons of the left group are near their mid-position. With the preferred firing order (4), the events occurring in each cylinder with this crank position are as follows, assuming that ignition has just occurred in

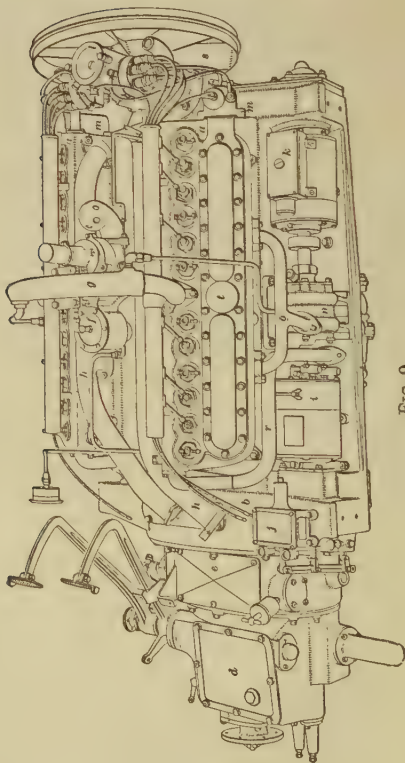


FIG. 9

cylinder 1 on the right: In cylinder 1 on right, the explosion stroke is beginning; in cylinder 2 on right, the piston is making the exhaust stroke; in cylinder 3 on right, the piston is on its compression stroke; in cylinder 4 on right, the suction stroke is beginning; the piston of cylinder 1 on left is on its exhaust stroke; the piston of cylinder 2 on left is on its suction stroke; the piston of cylinder 3 on left is on its explosion stroke, and the piston of cylinder 4 on left is on its compression stroke.

Twelve-Cylinder Engines.—Twelve-cylinder engines used in automobile work greatly resemble eight-cylinder engines in their general arrangement, in that the cylinders are arranged in two groups in two different planes, and that a crank-shaft having a number of crankpins equal to one-half the number of cylinders is used. In the twelve-cylinder engine, there are six cylinders in each group, the two sets making an angle of 60° with each other, and the pistons of each pair of opposite cylinders are connected to the same crankpin. The crank-shaft has the same crank arrangement found in the conventional six-cylinder engine; that is, the first and sixth crankpins, the second and fifth crankpins, and the third and fourth crankpins are in line, and each pair of crankpins that are in line make an angle of 120° with the other pairs.

The twelve-cylinder engine of the four-stroke cycle type possesses a great mechanical advantage over engines with less cylinders in that it produces a more even turning effort on the crank-shaft, there being six impulses per revolution.

A perspective view of a Packard twelve-cylinder unit power plant is shown in Fig. 9.

The two groups *a* of six cylinders each are cast en bloc, with detachable cylinder heads, and are bolted at an angle of 60° with each other to the upper half *b* of the aluminum crank-case, the lower part of which forms the oil reservoir. The transmission contained in the case *d* and the clutch in the case *e* are bolted to the engine crank-case. The intake manifolds are cast integral with the cylinder blocks and are surrounded by water; the fresh mixture is conveyed to them from the carbureter *f* by the water-jacketed, inverted, intake pipe *g*. The two exhaust manifolds *h* are separate from the cylinder blocks and are bolted to them. The electric starting motor *i* is at the

right side of the engine and through a sliding-gear starting transmission is connected to the flywheel for starting the engine; the switch for the starting motor is shown at *j*. The electric generator *k* is also located at the right side of the engine and is driven from the crank-shaft by a silent chain, which also drives the cam-shaft. Ignition is supplied by a dynamo-and-storage-battery ignition system employing a Delco timer-distributor *l* which has two distributor heads and two circuit-breakers, one for each set of cylinders, but only one cam, and has automatic spark advance. Each timer-distributor has its own transformer coil *m*. A forced-circulation cooling system with a double centrifugal pump *n* is used, the two impellers being in the same housing and each impeller serving its own set of cylinders; the impellers are driven by an extension of the generator armature shaft. The water connection to the water-jacket of the right cylinder block can be plainly seen at *o*; the connection to the left cylinder block is through a cylindrical passage lined with a drawn-brass tube, which is located in the upper half of the crank-case and extends clear across it, connection being made to the left water-jacket by a manifold similar to that shown at *o*. The bottom water connection, as well as the top water connections to the radiator, cannot be seen, owing to the view taken. To provide for a quick warming up of the engine, an automatic arrangement, known as a *thermostat*, which is set in action by a change in the temperature of the water, controls two throttle valves in the water piping in such a manner that upon starting the engine, with everything cold, the water circulates only through the water-jackets and back to the circulating pumps by way of the by-pass pipe *r*, none passing through the radiator. As the cooling water becomes warmer, the thermostat operates its throttle valves so as to pass more and more water through the radiator, until finally the by-pass *r* is completely thrown out of action, and the water circulates in the regular way through the water-jackets and radiator. A cast aluminum fan *s* driven by a built-up belt from a pulley on the forward end of the crank-shaft assists in cooling the water in the radiator by drawing air through it. On top of each block of cylinder castings there is a removable cap *t* that closes a passage through

which oil may be poured into the oil reservoir. Lubrication is by means of a high-pressure, forced, oiling system using a gear pump that forces oil under a normal pressure of from 20 to 30 pounds per square inch to the three main bearings of the crank-shaft, whence it passes through holes drilled in this shaft to the crankpins, and through a pipe attached to the side of each connecting-rod to each wristpin. The pistons, cam-shaft, etc. are lubricated from the oil spray thrown off from the crankpins and main bearings. The cylinders have a diameter of 3 inches and a stroke of 5 inches.

While there are a large number of possible firing orders with twelve-cylinder engines, only a few of these are used in practice. That employed in the Packard and also in the Pathfinder twelve-cylinder engine is 1 right-6 left-4 right-3 left-2 right-5 left-6 right-1 left-3 right-4 left-5 right-2 left. In the National twelve-cylinder engine the firing order is 1 right-6 left-5 right-2 left-3 right-4 left-6 right-1 left-2 right-5 left-4 right-3 left. In the Ferro twelve-cylinder engine the firing order is 1 right-1 left-5 right-5 left-3 right-3 left-6 right-6 left-2 right-2 left-4 right-4 left.

TWO-CYCLE AUTOMOBILE ENGINES

Two-stroke cycle, or, briefly, two-cycle, engines are those that require two strokes of the piston, or one revolution of the crank-shaft, to complete the cycle. This is accomplished by eliminating the suction stroke and the exhaust stroke of the four-cycle type of engine. Two-cycle engines of the type that has been used on automobiles are known either as *two-port* or *three-port* engines, according to the number of ports opening into the bore of the cylinder. At present no automobiles equipped with a two-cycle engine are built, excepting a few rare cases, but as many old cars using this form of engine are still in use, a description of it is believed to be warranted.

The principle of operation of two-cycle engines will be understood by referring to Fig. 10, which shows various positions of the piston of a typical form of two-port two-cycle engine. At *p* is shown the piston; *q*, the crank-shaft; *a*, the crank; *k*, the crankpin; *r*, the connecting-rod; *e*, the exhaust port; *o*, the inlet, or transfer, port; *b*, the transfer passage, or by-pass, leading

from the crank-chamber to the cylinder; *s*, the inlet valve in the crank-case; *d*, a deflector, or baffle plate, on the end of the

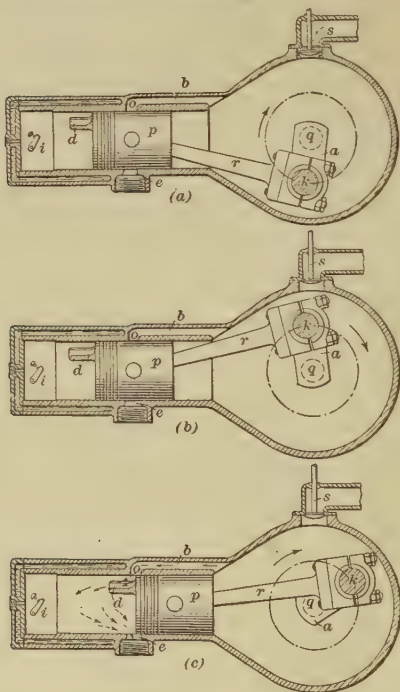


FIG. 10

piston, and *i*, the igniting device at which the spark is produced. In Fig. 10 (a), assume that the cylinder has been filled with

the combustible charge that the piston has compressed during its inward stroke. At the same time, the partial vacuum created in the crank-case by the inward stroke of the piston draws more combustible mixture into the crank-case through the inlet valve. The compression in the cylinder and the drawing of combustible mixture into the crank-case continue until about the end of the inward stroke. The compressed charge is then ignited, and the increased pressure due to the combustion drives the piston out on its impulse stroke. The outward motion of the piston slightly precompresses the mixture in the crank-case, the inlet valve having been closed at about the end of the inward stroke of the piston. This stage of the operation is illustrated in (b).

As the piston approaches the completion of the impulse stroke, it begins to uncover the exhaust port *e*. As soon as this port begins to open, the burned gases in the cylinder begin to escape into the atmosphere. This escape is, or should be, rapid enough to allow the pressure in the cylinder to fall below that of the precompressed combustible mixture in the crank-case by the time the piston has moved out far enough to begin to uncover the transfer port *o*, through which a fresh charge then begins to enter the cylinder and to drive out the burned gases.

In (c) the piston is shown expelling the burned gases as a fresh charge is being taken into the cylinder. The baffle plate *d* deflects the incoming charge, to prevent its flowing out with the burned gases. The expulsion of the burned gases and the drawing of a fresh combustible charge into the cylinder are accomplished during the time the piston is moving through a small portion of the latter part of the outward stroke and early part of the inward stroke. The ports are then closed by the piston during the early part of the inward stroke. The fresh charge is compressed in the combustion chamber, and more combustible mixture is drawn into the crank-case. A mechanically operated crank-case valve is used on some types of two-cycle automobile engines.

With the three-port type of two-cycle engine, instead of having an intake port that pierces the wall of the crank-case and is provided with a valve whose specific function is to close

the port at the proper times, as in Fig. 10, the intake port pierces the wall of the cylinder at a point near the crank-case, and the use of a valve is thus obviated. Such an engine, air-cooled and water-cooled forms of which are shown in Fig. 11, is known as a *valveless two-cycle engine*. The same letters of reference are used in each case.

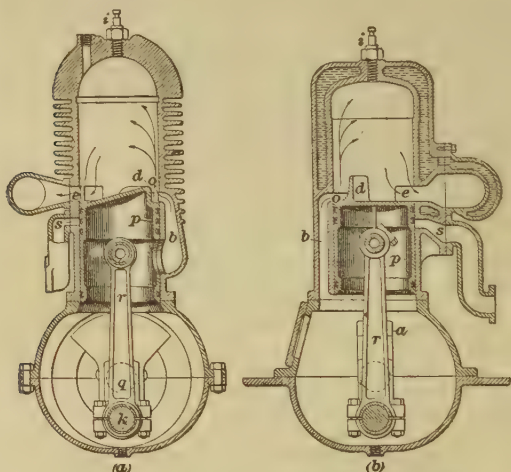


FIG. 11

In the valveless type of engine, the piston acts as a valve that mechanically opens and closes the intake port *s* through which the mixture is drawn into the crank-case for precompression. In the position of the parts shown, the piston has completed the power stroke and the incoming fresh charge is helping to drive the products of combustion from the cylinder. While the piston moves from its farthest out-position to its farthest in-position, it produces a partial vacuum in the crank-case, until the crank-case intake port *s* begins to be

uncovered. The mixture then flows into the crank-case through the port *s*; this flow is caused by atmospheric pressure. As the piston moves on its outward stroke, the intake port *s* is first covered, and then precompression of the mixture in the crank-case takes place; this continues until the piston has moved out far enough to open the transfer port *o* so that the precompressed mixture can flow into the combustion cylinder. Aside from the method of drawing the mixture into the crank-case, the operation of the valveless engine is the same as that of the two-port two-cycle engine with a valve in the port through which the mixture is drawn into the crank-case.

THE KNIGHT SLEEVE-VALVE ENGINE

In the *Knight sleeve-valve engine*, the admission of the fresh charge and the exhaust of the burnt gases are controlled by ports in two sleeves sliding within each other and the cylinder, instead of by poppet valves. A section through one cylinder of a six-cylinder Knight engine is presented in Fig. 12.

The piston *a* slides inside of the inside sleeve *b*, and is connected to the crank-shaft in the usual manner by the connecting-rod *c*. The outer sleeve *d* surrounds the inner sleeve and slides in the cylinder. The sleeves are connected by connecting-rods to small cranks on the valve shaft *e*, which turns at one-half the speed of the crank-shaft and is driven by a silent chain. The cranks on the valve shaft are so arranged that the crank for the inner sleeve is 70° in advance of that for the outer sleeve; the crank driving the inner sleeve is so placed in reference to the engine crank that it is practically

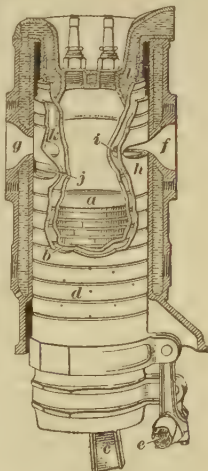


FIG. 12

on the bottom dead center when the engine crank is on the top dead center at the end of the exhaust stroke. An intake port *f* and an exhaust port *g* are cut through the cylinder walls. Inlet ports *h* and *i* and exhaust ports *j* and *k* are cut through the two sleeves at their upper end. The cylinder head *l* extends down into the inside sleeves and carries a packing ring, called a *junk ring*, at its lower end; this ring not only serves to make a tight joint between the inner sleeve and the cylinder head, but also performs a function in the closing of the inlet and the opening of the exhaust.

The operation of the sleeves is as follows: At the beginning of the intake stroke, the inner sleeve moves upwards and the outer sleeve downwards, bringing the ports *h*, *i*, and *f* into register; at this time the exhaust ports *g*, *j*, and *k* are closed. The inlet closes a little after the beginning of the compression stroke, through the lower inlet-port edge of the inner sleeve overlapping the lower edge of the junk ring in the cylinder head. When near the end of the explosion stroke, the exhaust port of the outer sleeve is partly in register with the cylinder exhaust port; the inner sleeve is then moving downwards very rapidly, and its lower exhaust-port edge in passing the lower edge of the junk ring opens the exhaust. Directly the exhaust stroke has been finished, the upper exhaust-port edge of the outer sleeve comes in line with the lower edge of the cylinder exhaust port, thereby closing the exhaust.

The time of the inlet and exhaust openings and closures can be varied through a fairly wide range by the designer, but cannot be readily changed after the engine has been built. Thus, in one make of the Knight engine, the inlet opens 8° past the top dead center and closes 30° past the bottom dead center; the exhaust opens 55° from the bottom dead center and closes 5° past the top dead center. In another make of the Knight engine, the inlet opens on the top dead center and closes 50° past the bottom dead center; the exhaust opens 60° from the bottom dead center and closes 15° past the top dead center. In still another make of the Knight engine, the inlet opens 20° past the top dead center and closes 40° past the bottom dead center; the exhaust opens 65° before the bottom dead center and closes 20° past the top dead center.

CYLINDERS

Cylinders for multi-cylinder automobile engines are made singly, in pairs, in sets of three, and all cylinders for the engine in a single casting. In the last case, the cylinders are said to be of the *monobloc type*; this type is now the one most widely used. Cylinders may be made with the body, the head, and the water-jacket in one casting; or, the head may be made separate and fastened on in some suitable manner, the cylinder body and water-jacket being cast in one piece; or, the cylinder head, cylinder body, and water-jacket may all be separate and fastened together in a suitable manner, this form of construction being obsolete, however. In some monobloc constructions, the cylinders, water-jackets, and upper crank-case are cast in one piece, with a separate cylinder head common to all cylinders. Several prominent automobile manufacturers that use the monobloc-cylinder construction, incorporate the inlet passages to each cylinder and sometimes also the exhaust passages from each cylinder into the casting in such a manner that there is no external branched inlet or exhaust piping.

The chief advantage of a monobloc construction is that it makes a very compact and simple engine; a disadvantage of this construction is that in case of an accident to one of the cylinders all must be replaced, instead of a single one, as would be the case if individual cylinders are used, or a pair if twin cylinders are used. To offset this disadvantage of the monobloc construction, some manufacturers point out that they furnish new monobloc cylinders for repair purposes at a very low price.

The manner in which one manufacturer constructs a detachable head and applies it to a four-cylinder monobloc engine is shown in Fig. 13. Here (a) presents a side view, partly in section, of the head and top of the cylinder casting; (b) is a top view of the engine; (c) is a bottom view of the detachable head removed from the cylinders; (d) is a top view of the cylinders with the head removed. When the head *a* is removed by unscrewing twelve capscrews *b*, the tops of the valves *c* and the tops of the pistons *d* are exposed, thus facilitating the processes of removing deposits of carbon, regrinding the valves, and removing the pistons and connecting-rods. As shown in view (a), the valve stems are kept cool by the

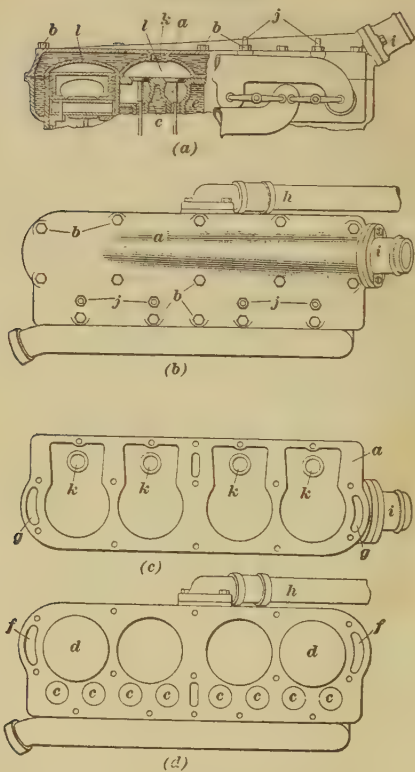


FIG. 13

water circulating in the jacket *e*, from which the water passes into the head through two passages *f*, one at each end of the cylinder casting, corresponding passages *g* being formed in the head, as shown by the bottom view of this part. The water that enters the water-jacket through the pipe *h* passes out to the radiator through the pipe *i* attached to the top of the head, as shown. The spark plugs *j* are screwed into the openings *k*, so as to project into the combustion chambers *l* formed in the head. A gasket is placed between the cylinders and the cylinder head in order to make a tight joint.

Most cylinders for automobile work are made of cast iron, but the use of aluminum alloys for cylinder castings is increasing. One prominent manufacturer of a high-grade American automobile employs a six-cylinder monobloc aluminum-alloy cylinder casting integral with the upper crank-case; cast-iron liners, or sleeves, are inserted in each cylinder. The cylinder head is a separate removable casting of cast iron, and carries the inlet valves, exhaust valves, spark plugs, intake ports, and exhaust ports, and also acts as a clamp for the six cylinder liners.

WATER-JACKETS

The *water-jacket* that surrounds the cylinder of an automobile engine is necessary in order to prevent the damage to piston and cylinder that would otherwise result from burning the oil used for lubricating them. Great care must be taken to select lubricating oils that will stand even as high temperatures as those reached in water-cooled cylinder walls. With such inflammable fuel as gasoline, it is necessary to keep the combustion chamber, the piston head, and the valves reasonably cool in order to avoid premature explosions due to hot cylinder walls. These walls are made hot by the high compression pressures commonly employed with the high-speed, or automobile, type of engine, as well as by the heat of combustion.

Water-jackets that are cast with the cylinder have the disadvantage that they cannot be readily cleaned when scale deposits accumulate in them, unless large holes closed by cover-plates are provided, as is done in some monobloc cylinders.

One disadvantage of integral water-jackets is the liability of having the cylinder walls uneven in thickness, through a shifting of the core in molding and casting the cylinder casting. This is avoided by making the water-jackets separate; this construction is rather expensive, however, and does not lend itself readily to a monobloc design, and for this reason is now but very little used.

COMBUSTION CHAMBER

The ideal combustion chamber is spherical in form, for the reason that a sphere has the least surface area for its cubical contents; hence, in such a combustion chamber the loss of heat through the walls is least. The nearest approach to an ideal combustion chamber in poppet-valve engines is found in valve-in-the-head motors, especially if the valves are set at an angle. The next-best approach to the ideal combustion chamber obtains in the type of engine having one valve overhead and one on one side of the cylinder; the next in order is the regular **L**-head motor, and finally the **T**-head motor. However, it should be clearly understood that while a construction may fail to approach that which is theoretically ideal, it may yet prove highly efficient and satisfactory in practice, as proved by the success attained by many **T**-head motors, in spite of their having the theoretically least efficient combustion chamber.

CRANK-CASES

The casing, or housing, of an automobile engine that encloses the cranks and crank-shaft, and, frequently, other moving parts as well, is called the *crank-case*. Besides forming a housing for most of the working parts, it also serves as a frame, or bed, that supports the crank-shaft and cylinders; and, usually, the lower part serves as a receptacle for the oil used in the lubrication of the engine. Crank-cases are generally cast of aluminum or an alloy of aluminum, although in rare cases manganese bronze, malleable iron, or cast iron is employed. Aluminum is used on account of its light weight in comparison with its strength. The size of a crank-case depends entirely on the design of the engine, but in any event it must be large enough to allow the cranks to rotate freely within it and strong enough to support the cylinders and crank-shaft.

Crank-cases are usually divided horizontally into two halves, which are bolted together. However, they are sometimes divided vertically, or they are made in single castings provided with openings for the connecting-rods and for inspection purposes. The type last named is known as the *barrel type*, and is practically obsolete.

The most common type of automobile-engine crank-case is that in which the case is divided horizontally into two halves and the crank-shaft bearings are supported entirely from the

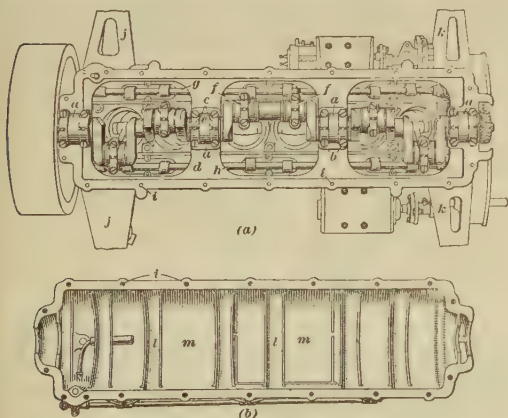


FIG. 14

upper half. This type of crank-case is illustrated in Fig. 14. In (a) is shown a bottom view of the upper half, and in (b) a top view of the lower half of the crank-case. There are four crank-shaft bearings *a* in this case. The lower half of each bearing is a cap held in place by capscrews *b*, which are prevented from turning by keepers *c*; the capscrews are screwed into the supports *d*. Movement of the keepers *c* is prevented by pins *e* that extend through the keepers and have cotter pins

passed through them. The object of the keepers is to prevent the capscrews from turning under the influence of vibration. The connecting-rod bearing caps *f* are fastened in the same manner. The engine is of the T-head cylinder type, the valves being operated from cam-shafts *g* and *h*, which are located on opposite sides of the crank-shaft.

The lower half of the crank-case is attached to the upper half by means of bolts that pass through the holes *i*, and the entire case is supported from the frame of the automobile by the arms *j* and *k*. The lower half is provided with the oil troughs *l*, into which the ends of the connecting-rods dip in order to lubricate the moving parts of the engine. The bot-

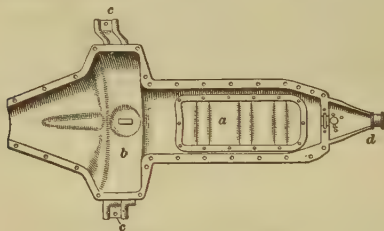


FIG. 15

tom *m* of the case, beneath the oil troughs, is used as an oil well, or reservoir.

In most cases the oil reservoir is an integral part of the lower half of the crank-case. In some instances the lower crank-case is made of pressed steel, and in others it is a casting. Sometimes the troughs are made of sheet metal and inserted into the lower half of the crank-case.

For unit power plants, crank cases are made with an enlarged extension at the rear, which often encloses entirely the fly-wheel and clutch; the bell housing of the transmission then bolts to the rear of the crank-case extension. In many instances the crank-case extension does not entirely enclose the flywheel and clutch, the extension being left open to give free access to the clutch.

The most familiar example of a crank-case that is supported by its lower half is illustrated in Fig. 15, which shows a top view of the bottom half of the crank-case used on the Ford model T automobile. The crank-shaft bearings are carried by the upper half of the case, which is of cast iron and is cast integral with the four cylinders. The lower half is of pressed steel and is bolted to the upper half. An inspection plate *a* is bolted to the bottom half and can be removed for inspection purposes. The rear end *b* encloses the flywheel and transmission gears and is supported by two arms *c* that are fastened to the case. The front end is supported at a single point *d*, thus forming the three-point suspension method of support.

The crank-cases of four-cycle engines are provided with one or more openings to which are attached pipes, called *breathers*, that allow the escape of air and hot gases. With the four-cycle engine, an air-tight crank-case would not be advantageous, because where the hot gases leak past the piston rings into the crank case, there would be a tendency to overheat the bearings and to burn the oil, and through imperfect lubrication rapid wear of the engine would result. The breathers prevent this by allowing these hot gases to escape. In addition to this, the pressure in a closed crank-case of a multiple-cylinder engine varies because of the movements of the reciprocating parts; hence, another use of the breather is to relieve this pressure variation and keep it the same at all times. Varying pressures in the crank-case might interfere with the proper working of the lubricating system by forcing the oil out of the crank-case through the joints or bearings. Crank-case breathers usually, but not in every case, serve the purpose of oil filling tubes, through which the lubricating oil is poured into the lower half of the case.

Breathers are usually located in the upper part of the crank-case and are frequently placed on the supporting arms. Occasionally they are cast integral with the case, but more often they are separate pipes bolted on.

Crank-case breathers vary greatly in details of construction and in method of attachment, but they are all used for the same purpose.

CONSTRUCTION OF PISTONS

The pistons of automobile engines are made hollow to receive one end of the connecting-rod, as shown in Fig. 16. Such pistons are of the so-called *trunk type*, being constructed in this way so as to obviate the use of a crosshead and guides. The piston consists of a casting carefully machined to a good working fit. Near the head end of the piston there are three or more grooves *a* in which are placed *piston rings* to make a tight joint between the piston and the cylinder.

Smaller grooves *b*, Fig. 16 (*a*), are sometimes turned in the piston to aid in distributing the lubricating oil to all parts of the cylinder wall. Some pistons have oil grooves of various

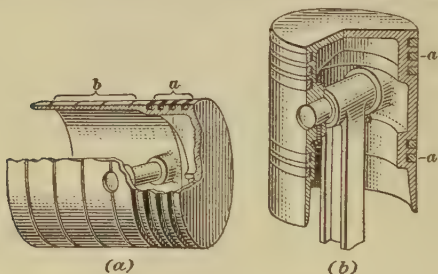


FIG. 16

shapes between the grooves *b* and the piston rings, and others, either with or without oil grooves, have one or two piston rings on the crank end of the piston, as shown in (*b*). The piston is usually made to taper slightly from the head end to the crank end, to allow for more expansion at the hottest end.

Piston pins are mounted in the piston in two ways: they are either secured to the piston casting at each end, the central part having a bearing in the small end of the connecting-rod, or they are fastened to the upper end of the connecting-rod and have bearings in the piston casting.

Cast-iron and semisteel castings were formerly used exclusively for pistons, but their comparatively great weight pre-

vented the attainment of high speeds without undue vibration. Various expedients have been resorted to in order to reduce the weight of pistons, such as drilling a large number of holes in them, making them of pressed steel, etc., but the best solution of the problem is probably found in the substitution of a suitable aluminum alloy for cast iron or semisteel. Quite a number of engine builders now furnish aluminum-alloy pistons as regular equipment; quite a large number of concerns specialize on furnishing aluminum-alloy pistons for old engines. The desire for extreme lightness has led to the design of pistons differing very much from those shown in Fig. 16; two commercial forms of

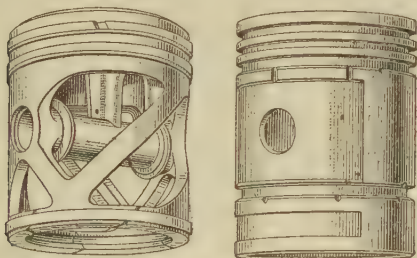


FIG. 17

aluminum-alloy pistons are shown in Fig. 17. It is claimed by advocates of aluminum-alloy pistons that carbon does not deposit on their heads as much as with cast-iron pistons. A drawback to the use of aluminum-alloy pistons is that, owing to the greater coefficient of expansion of aluminum, the pistons must be given about twice the clearance in the cylinders, and therefore a disagreeable piston slap accompanies their use, at least when starting up the engine. This piston slap disappears, however, when the engine is warm.

The experience of different concerns using aluminum-alloy pistons seems to be at variance in respect to their wearing qualities as compared with cast-iron pistons. Some concerns that have changed over from cast-iron pistons, have changed

back; others continue the use of aluminum-alloy pistons and report them satisfactory in every respect.

PISTON RINGS

It not being possible to make a solid piston air-tight and at the same time a free running fit in the cylinder of an automobile engine, the piston is fitted with expansible rings called *piston rings*, in order to make the required air-tight joint. These rings are usually made of close-grained cast iron and are sprung or *snapped* over the piston into grooves turned therein, and therefore they are often referred to as *snap rings*. While cast iron is the usual material for piston rings, at least one make on the market is made from soft steel.

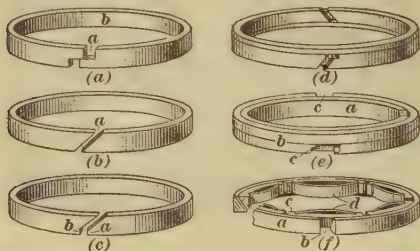


FIG. 18

Piston rings are made of such diameter that they press lightly against the wall throughout their entire circumference. The joints in the ring where it is split are made in several different forms, some of which are illustrated in Fig. 18.

The piston ring shown in (a) is of uniform cross-section, with the ends lapped at the parting, as shown at *a*. This type of ring is frequently made eccentric; that is, thinner at the ends than at the back *b*. The parting in the ring shown in (b) is a diagonal split, as shown at *a*; it is less liable to cut or scratch the cylinder than the one shown in (a), as no part of its parting line is parallel with the motion of the piston. The parting of

the ring shown in (c) is also diagonal, but it differs from that shown in (b) by having the point *a* made square and a notch *b* milled in the opposite corner of the other end, thus forming a rectangular space between the ends of the ring. Into this space fits a pin that holds the ring in place in the groove. A two-piece concentric ring is shown in (d). One ring is placed within the other, and each ring has a flange that extends over the other, closing each opening. This form of ring is known to the trade as the *Leakproof ring*. A composite type of ring is shown in (e). This ring consists of a heavy, plain, wide ring *a*, on the outside of which are two thin rings *b* split at *c* on opposite sides and pinned, as shown, quartering the split in the inner ring. The office of the heavy inner ring *a* is to produce the expansive force, while the thin outer rings conform perfectly to the shape of the cylinder. In (f) is shown a sectional piston ring. It consists of an outside ring *a*, which is parted at *b*, and six inner segments *c*, each of which is provided with a flat spring *d*. When the ring is placed in its groove, the springs force it outwards against the cylinder wall. The outer ring and the inner segments are of triangular cross-section; hence, when the springs expand the segments, they tend to slide on the outer ring and fill up the groove endwise.

The three commonest forms of piston rings are those shown at (a), (b), and (c); these rings when very carefully fitted to new engines work very well indeed, giving good compression for a long time. When the cylinders are worn, however, only indifferent results are gotten by fitting new piston rings of this type, no matter how carefully the work is done, because they must be made small enough to enter the unworn part of the cylinder (this statement refers to engines in which the piston must enter the cylinder from the bottom end), and consequently there will be a large opening at the split when the piston is connected in place. Much better results will be obtained in the case mentioned if one of the many types of non-leak piston rings that are on the market are fitted. These piston rings are the product of specialists, have sealed openings, and can be obtained through garages and automobile supply houses at a very reasonable price. In cylinders fitted with removable heads the construction often permits removal of the piston

through the top; when this is the case the top piston ring usually overrides the cylinder bore so that no shoulder can be formed by wear. With such construction, satisfactory results can often be obtained by fitting new plain split rings.

When new piston rings have been fitted to an old engine, the looked-for improvement in the compression, even with rings of the non-leak type, is often disappointing. This is simply because the new rings do not conform perfectly to the walls of the cylinder as yet, but as they wear in with use of the car, the compression will, as a general rule, get better. It takes an average of 500 miles use of the car to wear new piston rings to a proper bearing.

New piston rings will not cure lack of compression due to badly scored cylinders; such cylinders must first be rebored, reground, or otherwise repaired, or, if necessary, replaced by new ones.

CRANK-SHAFTS

Crank-shafts for automobile engines are made of special grades or alloys of steel, so that they may be as light as possible and yet be strong enough to resist the twisting and bending action to which they are subjected, the bearing portion being made sufficiently ample to withstand the wear due to continuous rotation at high speed. Automobile-engine crank-shafts are usually made in one piece, and are either machined from a rough flat forging or drop-forged in dies.

Typical crank-shaft arrangements for four- and eight-cylinder engines and six- and twelve-cylinder engines are shown in Fig. 19. In (a) is shown a two-bearing crank-shaft. A three-bearing crank-shaft is shown in (b), and a five-bearing crank-shaft is shown in (c); all three crank-shafts are for four-cylinder and eight-cylinder engines. The illustrations show the universal crank arrangement, the two outer crankpins being in line, and the two inner crankpins being in line, with the inner and outer crankpins 180° apart. A seven-bearing crank-shaft for a six-cylinder or twelve-cylinder engine is shown in (d); some makers provide three and some four main bearings, however. Two-bearing crank-shafts are not used in practice in six-cylinder and twelve-cylinder engines.

While the crank-shafts shown in Fig. 19, when properly made, are in static and dynamic balance, at very high engine speeds they are liable to cause vibration, in conjunction with the influence of the reciprocating parts. This has been over-

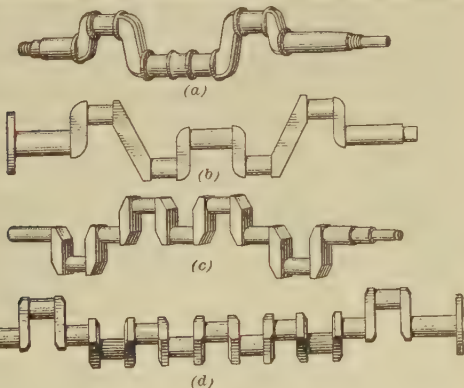


FIG. 19

come of late partly by lightening of the reciprocating parts and partly by a system of counterbalancing of the crank-shaft, suitable counterbalance weights being welded or otherwise fastened to the webs of the cranks on the side opposite the crank-pins.

VALVES

A *poppet valve* consists of a disk with a stem at right angles to the plane of the disk. The valves open in the direction of the stems and are held to their seats by springs. The valve seats are usually made of cast iron. Tungsten steel has become quite popular for exhaust valves when the head and stem are made in one piece; it is also used extensively for the heads of built-up valves having the stems made of machinery steel. It is claimed that valves made of tungsten steel will neither warp nor scale from excessive heat. Nickel steel is also used

for valves. The valve seats are occasionally flat, though more frequently they are beveled to an angle of 45° .

A valve that is opened by mechanical force applied by rigid parts is called a *mechanically operated valve*. An exhaust valve of the poppet type must always be mechanically operated. The inlet valve, however, can be so constructed as to be opened by the pumping action of the piston during the suction stroke. When thus opened it is known as an *automatic inlet valve*; such inlet valves are not used on modern automobile engines, although they were very popular at one time.

The valve seats with the valves assembled therein are sometimes made separate from the cylinders and hence can be readily removed for inspection and repair; they are usually employed in engines having the valves in the cylinder head. The casting containing the valve is called the *valve cage*.

When overhead valves are employed with removable cylinder heads, caging of the valves is usually dispensed with, as removal of the cylinder head gives full access to the valves.

VALVE SPRINGS

All poppet valves are held to their seats by springs, which are held in place, as a general rule, by a cup-shaped washer on the valve stem that fits over a pin or key passed through a transverse hole in the valve stem; or, a groove is turned in the stem and a horseshoe-shaped collar is slipped into the groove. Valve springs are made either of spring-steel wire or of regular tool-steel wire; they are wound cold over a mandrel of the correct size to a helical form, as a general rule. If tool steel wire is used, the springs have to be hardened and tempered before they are ready for use; if spring-steel wire is used, no further heat treatment is necessary.

VALVE-ACTUATING DEVICES

With poppet-valve automobile engines, the valves are invariably operated by *cams*, the contour of the cams having much to do with the silent-running qualities and the efficiency of the engine.

Cams vary considerably in shape, or profile, the outline depending to some extent on the type of *cam-follower*, or *valve*

lifter, which is the part of the valve-lifting mechanism that is in contact with the cam. An inlet-valve cam designed to be used with a roller follower is shown in Fig. 20 (a), and the corresponding exhaust-valve cam is shown in (b). Another common form of cam, also used with a roller follower, is shown in (c). In (d) is shown a cam having rising and falling shoulders of convex form, giving a gradual opening and closing. This form of cam is used with a mushroom, or flat-bottomed, cam-follower.

If the inlet and exhaust valves of an automobile engine are located at the sides of the cylinders, they are usually oper-

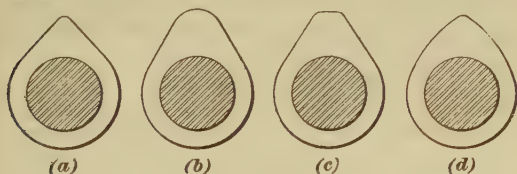


FIG. 20

ated directly from cams acting on valve lifters, which are placed between the cams and the valve stems. There are various designs of valve lifters; some are flat where they rest on the cams, others are rounded off, and still others are provided with rollers at the bottom end. The majority of makes of valve lifters are provided with some means of adjusting their length; usually an adjusting screw is placed in the upper end.

Overhead valves, as a general rule, are operated by rocker-arms, although in rare instances an overhead cam-shaft is used.

Formerly it was the common practice to make the cams separate from the cam-shaft and to fasten them thereto by keys, taper pins, or screws. This practice has been superseded,



FIG. 21

however, by making the cams integral with the cam-shaft, as shown in Fig. 21.

The valves may be operated from a single cam-shaft, which in this case carries all the inlet and exhaust cams, or they may be operated from two cam-shafts, one at each side of the engine, the one cam-shaft carrying the inlet cams and the other the exhaust cams.

With four-cylinder and six-cylinder engines having all cylinders in one plane it is necessary to have two cams, one inlet cam and one exhaust cam, for each cylinder. With eight-cylinder and twelve-cylinder V-type engines, however, it is possible to get along with only one inlet cam and one exhaust cam for each pair of cylinders, the pistons of which are connected to the same crankpin. Most builders of V-type engines provide two cams for each cylinder, however.

VALVE-TIMING PRACTICE

In an article by J. Edward Schipper in *The Automobile*, the author presents the results of an investigation into the valve timing of the engines of sixty-eight representative American cars. This investigation showed that on 11.9 per cent. the opening of the intake valve and the closure of the exhaust valve occurred at the same point of the piston stroke; on 66.6 per cent. the intake valve opens after the exhaust valve has closed, and on 21.5 per cent. the intake valve opens before the exhaust valve has closed. The closing of the intake valve occurred all the way from 15° to 54° past the bottom dead center. The point of opening of the exhaust valve varied from 60° to $27\frac{1}{2}^{\circ}$ before the bottom dead center; the closing of the exhaust valve varied from 0° to 21° after the top dead center; the opening of the intake valve varied from 3° to 21° after dead center.

Striking the average of the sixty-eight cars investigated, Mr. Schipper found that the average practice was as follows: Inlet valve opens 11.2° after top dead center and closes 35° after bottom dead center; exhaust valve opens 50° before bottom dead center and closes 9.3° after top dead center.

The investigation of Mr. Schipper covered four-cylinder and six-cylinder engines; the timing of eight-cylinder and twelve-cylinder engines does not vary to any very great extent from the values that have been given. Thus, one Northway eight-

cylinder unit power plant has the following valve timing: The inlet valve opens 15° after the upper dead center is passed and closes 38° after the lower dead center is passed; the exhaust valve opens 45° before the lower dead center is reached and closes 10° after the upper dead center is passed.

WATER-COOLING SYSTEMS

In an internal-combustion engine, unless provision is made for cooling, the heat from the explosion of the charge will raise the temperature of the cylinder walls and piston so high as to render lubrication impossible. The devices employed for cooling purposes comprise the *cooling system* of the automobile. Most automobile engines are cooled by circulating water through the space between the outer wall of the cylinder and a jacket casing that surrounds the cylinder head and the part of the cylinder barrel nearest the head. Air is used for cooling in only a very small proportion of automobile engines. An objection to the use of water is its liability to freeze. To overcome this objection, various substances are added to the water to lower its freezing point.

The water used for cooling enters the cylinder water-jacket space generally at its lowest part, and flows out at the highest part. It is important to have the water flow from the highest part, because a pocket would be formed if a portion of the water space were higher than the outlet. It is not necessary, however, that the circulating water should enter the jacket at the extreme lowest portion; in some engines the water enters just beneath the exhaust port. The hot water from the jacket passes through pipes to a *radiator*, where it is cooled, and from the radiator it passes back to the jacket space of the engine again. Circulation is maintained either by a pump, which forces the water through the system, and which on this account is called a *forced-circulation system*, or by *thermal circulation*, which means circulation due to the heating of the water.

The thermal circulation, or *thermo-siphon cooling system*, is characterized by the absence of a circulating pump, the circulation being established and maintained by heating the water to a higher temperature in the water-jacket of the cylinders than in the remainder of the cooling system. Inasmuch as

hot water is lighter than cold water, it tends to flow upwards; conversely, cold water is heavier than hot water and tends to flow downwards.

The most widely known example of a thermo-siphon cooling system is found in all Ford model T cars having a manufacturer's number higher than 2,500. Cars of this model bearing a lower number were fitted with a forced-circulation system.

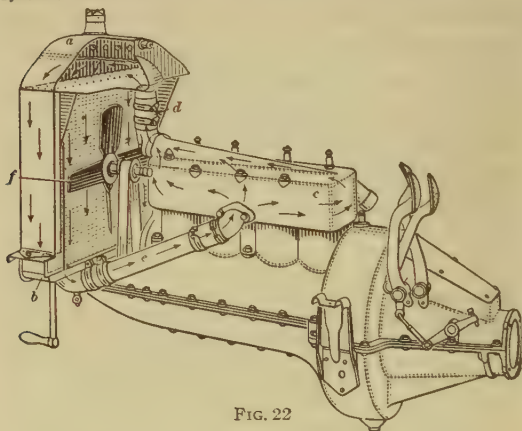


FIG. 22

The radiator consists of an upper tank *a*, Fig. 22, and a lower tank *b* united by a large number of vertical tubes supplied with horizontal cooling fins. The water-jacket *c* surrounds the upper part of the four cylinders, which, together with the upper half of the crank-case, are a monobloc casting. The heated water passes from the water-jacket through the upwardly inclined connection *d* to the upper tank *a* of the radiator, flows downwards through the vertical tubes, where it is cooled by air passing over them, and drops into the bottom tank *b*, whence it flows upwards again through the connection *e* to the bottom of the water-jacket, taking the place of the heated water that

flowed from the top of the water-jacket. A fan *f* located behind the radiator and driven by the engine draws air rapidly over the radiator tubes and thus assists the cooling of the water.

A forced-circulation cooling system is shown in Fig. 23, where part of the water-jacket is broken away and the radiator, as well as the pump, is illustrated in section. The

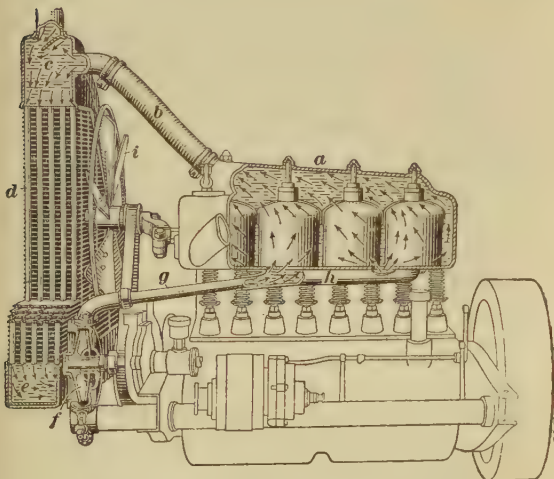


FIG. 23

cooling water passes from the top of the water-jacket *a* surrounding the upper end of the four cylinders through a flexible hose connection *b* to the upper tank *c* of the radiator; it then passes downwards through the radiator tubes *d*, which are surrounded by horizontal fins soldered to them, to the bottom tank *e* of the radiator. This bottom tank *e* is connected by a pipe, which cannot be seen in the view given, to the casing

of the circulating pump *f*, which pump is driven from the engine cam-shaft and delivers the cooling water through the pipe *g* to a manifold *h* attached to the bottom of the water-jacket. This manifold has two outlets into the water-jacket in order to insure a better distribution of the cooled water than is possible with a single outlet. The fan *i*, which is rotated at a high speed by the engine, draws air over the tubes *d* of the radiator and their surrounding fins, thereby abstracting heat from the cooling water; that is, cooling it.

With an engine having monobloc cylinders, as shown in Fig. 23, a single outlet from the top of the water-jacket is usually sufficient. When the engine has individual cylinders or twin cylinders or triple cylinders, there must be a manifold to convey the cooling water to and from the water-jackets of the cylinders.

To provide for a quick warming up of the engine, some automobile manufacturers are fitting to forced-circulation cooling systems an automatic arrangement known as a *thermostat*, which is set in action by a change in temperature of the cooling water. This thermostat, when the engine is cold, cuts the radiator out of the cooling system, so that the water circulates only through the water-jackets and circulating pump. Owing to the small quantity of water in circulation, it heats up quickly and acts upon the thermostat, which opens up a passage to the radiator that gradually increases in size as the water temperature rises, until the radiator is fully in action.

If a car is to be used in very cold weather the cooling system should be filled with some liquid that will not readily freeze. In weather not colder than 10° F. above zero, especially if a wind is blowing, it requires only a short time for water to freeze in the radiator if the engine is stopped out of doors. The freezing may be prevented for a considerable time, however, by covering the radiator with a blanket or a robe. If wood alcohol is mixed with water, it will lower the freezing point. The table gives the approximate freezing temperatures for various proportions of the alcohol and water. The wood alcohol vaporizes and passes out of the cooling system more rapidly than does water. It is therefore necessary in order to maintain the proper proportions to add more alcohol than fresh water.

If denatured alcohol is available, it may be used in place of wood alcohol.

FREEZING POINT OF MIXTURES OF WOOD ALCOHOL AND WATER

Percent- age of Alcohol	Percent- age of Water	Freezing Point of Mixture Degrees F.	Specific Gravity at 60° F.
10	90	23 above zero	.987
20	80	10 above zero	.975
30	70	2 below zero	.963
40	60	20 below zero	.952
50	50	40 below zero	.937

Calcium chloride dissolved in water forms a solution that will not freeze so rapidly as water alone. Only chemically pure chloride should be used, however. The table gives the approximate freezing points of various proportions of this mixture of calcium chloride and water.

FREEZING POINT OF CALCIUM-CHLORIDE-AND WATER MIXTURES

Calcium Chloride per Gallon, of 231 Cubic Inches, of Water Pounds	Freezing Point Degrees F.
1.0	27.0 above zero
2.0	18.0 above zero
3.0	1.5 above zero
3.5	8.0 below zero
4.0	17.0 below zero
5.0	20.0 below zero

Glycerine and water also form a mixture that stays liquid at a lower temperature than water alone. The glycerine, however, attacks and destroys the rubber in hose connections, etc.

FREEZING POINT OF MIXTURES OF WOOD ALCOHOL, GLYCERINE, AND WATER

Percentage Alcohol	Percentage Glycerine	Percentage Water	Freezing Point of Mixture. Degrees F.
5	5	90	25 above zero
10	10	80	16 above zero
15	15	70	5 above zero
20	20	60	11 below zero
25	25	50	31 below zero

Instead of using a mixture of just these two liquids, wood alcohol is often added. The preceding table gives the approximate freezing points of various mixtures of this kind.

RADIATORS

Radiators are usually made of thin metal, with as much surface exposed to the air as possible, and they are arranged so that the air can circulate through them easily. The air circulation in modern practice is aided by a fan placed behind the radiator and driven by the engine, either by belting or by gearing. Broadly speaking, a radiator as at present constructed consists of two headers, or tanks, one at the top and one at the bottom, joined either by vertical tubes with air spaces between them, or joined by water passages formed in some suitable manner to be the equivalent of vertical tubes. Radiators with horizontal tubes are obsolete. It was formerly the practice to make the tanks of highly polished brass or German silver, or nickel-plated brass, and this practice is yet followed to some extent. The modern practice is to place a shell, usually pressed from sheet steel of fairly heavy gauge, over the outside of the radiator; this shell then serves to support the radiator in the frame of the car and also supports the hood over the engine. This construction is shown in Fig. 24, where *a* is the radiator core, *b* the top tank, *c* the bottom tank, *d* the water inlet from

the top of the water-jackets of the engine, *e* the water outlet to the circulating pump, and *f* the overflow pipe. The shell *g* is entirely separate, is pressed to shape in one piece, and is slipped bodily over the core and tank assembly, to which it is fastened in the case shown by screws passing through the lugs, or brackets, *h*. The shell in this case is provided with pockets, as *i*, in which silencer pads of leather or some asbestos brake-lining fabric are held; the hood, the top hinge of which is supported by the hood support *j*, then rests on the silencer pads. Modifications of the construction shown in Fig. 24 are in use. By placing the radiator core and tanks inside a shell, substantially as shown, they are greatly protected from injury by vibration and twisting of the frame; furthermore, the shell being separated some distance from the tanks, it does not get hot enough to spoil the finish, which may be enamel baked on, or varnish.

There are two general types of radiators, which are named in accordance with their construction. One of these types is spoken of as the *tubular radiator*, the cooling being done by passing the heated water through round or flat tubes around which air circulates to abstract heat and carry it away. The second type is known as the *cellular radiator*, from the general resemblance it bears to a mass of cells; in this type of radiator the water to be cooled surrounds the cells and the air that abstracts and carries away heat passes through the cells.

Tubular radiators nearly always have the tubes surrounded by a large number of thin fins, or gills, that are soldered to them, the object of these fins being to increase the radiating surface to an extent sufficient to produce satisfactory cooling.

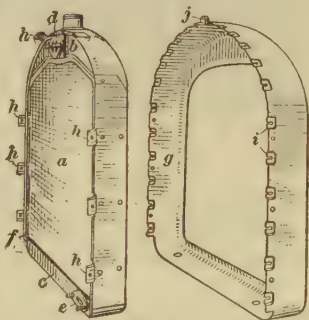


FIG. 24

Radiators of the tubular type may be divided into two general classes; namely, (1) radiators in which each tube has its own fins, and (2) radiators in which the fins are common to all the tubes. At one time radiators belonging to the first class were very extensively used, but of late years radiators of the second class have displaced them to a large extent for pleasure-car use.

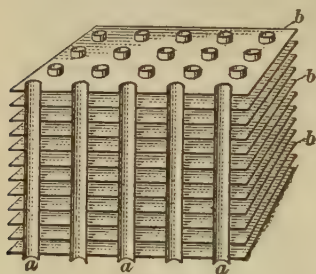


FIG. 25

The general assembly of radiator tubes with fins common to all tubes is shown in Fig. 25, which represents a small section cut from

a radiator. The tubes *a* are usually from $\frac{1}{4}$ to $\frac{5}{16}$ inch in outside diameter and are vertical; they are spaced approximately 1 inch from center to center lengthwise of the radiator and $1\frac{1}{2}$ inches from center to center crosswise. The fins *b* are placed horizontal; each fin is made from flat stock with holes

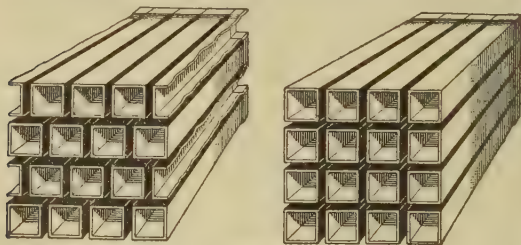


FIG. 26

punched therein to fit the tubes *a*, and of a length sufficient to reach from the left to the right side of the radiator. Although

circular tubes are shown in Fig. 25, some manufacturers use flat tubes, placing the narrow side forwards.

In order that the fins may assist in cooling, they must be in intimate metallic contact with the tubes; to insure this contact, they are soldered to the tubes.

The group of cells around which the water circulates in radiators of the cellular type is formed in various ways. In one construction in wide use, the cells are formed of individual tubes of square or hexagonal cross-section that are laid side by side, as shown in

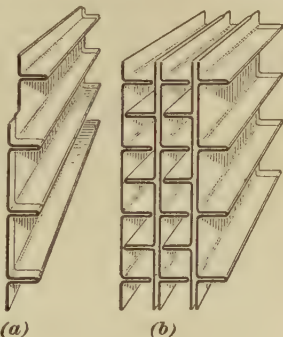


FIG. 27

Fig. 26, in such a manner that there is a water space around them. In another widely used construction sheets of metal are bent to form cells that have water spaces around

them when suitably assembled. It is urged in favor of the individual-tube construction that, in case of leakage, repairs can be executed with great facility by any one expert in the use of a soldering iron, as a tinsmith, for instance.

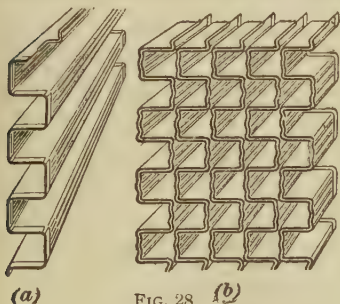


FIG. 28

are formed by bending long strips of sheet metal, usually sheet copper or sheet brass, frequently have their cores made from

Cellular radiators in which the cells

strips bent as shown in Figs. 27 (a) and 28 (a). These strips have a width equal to the desired depth of the radiator core, and are assembled as shown in Figs. 27 (b) and 28 (b), thus forming water spaces ranging from $\frac{3}{64}$ to $\frac{1}{16}$ in. in width and having a depth about $\frac{1}{4}$ in. less than the depth of the core. The ends of the water spaces are closed by soldering.

EXHAUST MUFFLERS

Gases exhausting unrestricted from the cylinder of an internal-combustion engine pass into the atmosphere at such a high velocity, especially at high speeds, that the result is a continuous noise that can be likened to a series of sharp detonations. This noisy exhausting of the gases is so objectionable that many efforts have been made to produce a device that will muffle the detonations to a degree that will render them unobjectionable. The device used for this purpose is called an *exhaust muffler*.

Generally speaking, the exhaust may be muffled by leading the exhaust gases into one or more chambers, where they can expand to a low pressure and cool at the same time. In most mufflers, the single large stream of exhaust gases coming from each cylinder is broken into numerous small streams, or thin sheets, to insure rapid cooling and reduction in velocity. In some mufflers, the cooled exhaust gases are discharged into the atmosphere in a series of fine streams; in others, especially the most modern, the discharge is in a single stream. It is common practice to place a valve of some suitable form between the muffler and the engine, or to incorporate a valve directly with the muffler, the valve being operated by a conveniently located foot-pedal. This valve, known as the *muffler cut-out*, opens directly to the atmosphere, and, when open, it allows the engine to exhaust directly into the air, for testing the regularity of the explosions. A good muffler, when effectively muffling the sound of the escaping exhaust gases, will not create an excessive back pressure on the engine; hence, contrary to common belief, there is no appreciable gain in power obtainable through opening the muffler cut-out.

AUTOMOBILE CARBURETERS

COMBUSTION AND FUELS

Definitions.—When a combustible vapor and air are mixed in proper portions and ignited, the combination of the gas with the oxygen of the air is so rapid as to produce an *explosion*, which may be defined as an extremely rapid combustion accompanied by the formation of gases and increased pressure. Two or more elementary substances may be mixed together and yet not combine to form a new substance. They are then said to form a *mixture*.

A mixture of two or more substances whose chemical combination will cause an explosion is called an *explosive mixture*. An explosive mixture of gasoline vapor and air is composed of the vapor of 1 part of liquid gasoline to from 8,000 to 10,000 parts of air, by volume. The volume of the vapor will vary, but an average proportion will be 2.15 parts of gasoline vapor to 100 parts of air.

The enriching of air, as by adding to it the vapor of gasoline, naphtha, kerosene, alcohol, etc., is called *carburation* of the air; the device used for carbureting the air is called a *carbureter*. The mixture formed is variously called the *combustible mixture*, the *gas*, or simply the *mixture*.

The internal-combustion engine used on automobiles burns the fuel inside the engine, as the name indicates. The fuel used is generally gasoline; less frequently, it is stanolind, benzol, alcohol, and, in rare cases, kerosene. All these fuels are liquids in the commercial form. The burning, or combustion, of the fuel liberates *heat*, which is a form of energy. The function of the engine is to convert some of this heat energy into mechanical energy which can be utilized to perform the work of driving the car.

Gasoline.—Internal-combustion engines equipped with carbureters use fuels composed of hydrogen and carbon. *Gasoline* is in most general use, and its behavior is typical of all fuels used in engines of this class. It is produced in the early stages of the distillation of petroleum, and is a mixture of various substances of different evaporative rates depending on the

extent to which the distillation is carried. At one time, gasoline was much cheaper than kerosene, and the tendency of the refiner was to produce as small a proportion of gasoline as possible from the crude oil; in other words, to market gasoline of a high evaporative rate. The development of this type of engine for automobile use, however, has created a demand for gasoline that has raised its price considerably, and the refiners now produce more gasoline from the same crude oils. As a result, the commercial gasoline of today has a much lower evaporative rate than formerly, and there is a tendency toward the production of still heavier gasoline.

Gasoline is particularly adapted to use in modern high-speed automobile engines on account of its high evaporative rate at moderate temperatures, evaporation being essential to thorough mingling and complete combustion of the charge in the limited time available. It is not, however, a substance having a definite chemical composition, but a mixture of various substances having different evaporative rates. At low

temperatures, certain of these substances are not readily vaporized so as to give their maximum effect in the engine. In fact, vaporization is sluggish at very moderate temperatures, owing to the cooling effect of the evaporative process on the inspired charge and on the carburetor and intake pipes. This is illustrated on starting a cold engine in cold weather, when a considerable excess of fuel makes starting easier. The excess is required because only the lighter portions of the fuel are evaporated at that temperature and are available for ignition, the heavier portions being inert. The ordinary gasoline of commerce averages between 58° and 62° Baumé; higher grades, as a general rule, can only be obtained on special order.

Baumé Hydrometer.—The specific gravity of gasoline, being less than that of water, is determined by means of *hydrometers* made for liquids lighter than water. A Baumé hydrometer made especially for testing gasoline, and shown in Fig. 1, consists of a glass



FIG. 1

tube, near the bottom of which are two bulbs. The lower and smaller bulb is loaded with mercury or shot, so as to cause

SPECIFIC GRAVITIES CORRESPONDING TO BAUMÉ'S READINGS FOR LIQUIDS
LIGHTER THAN WATER

Degrees Baumé	Specific Gravity	Degrees Baumé	Specific Gravity	Degrees Baumé	Specific Gravity	Degrees Baumé	Specific Gravity	Degrees Baumé	Specific Gravity
20	.9333	38	.8333	56	.7526	70	.7000	79	.6698
22	.9210	40	.8235	58	.7446	71	.6965	80	.6666
24	.9090	42	.8139	60	.7368	72	.6931	81	.6635
26	.8974	44	.8045	62	.7290	73	.6896	82	.6604
28	.8860	46	.7954	64	.7216	74	.6863	83	.6573
30	.8750	48	.7865	66	.7142	75	.6829	84	.6542
32	.8641	50	.7777	67	.7106	76	.6796	85	.6481
34	.8536	52	.7692	68	.7070	77	.6763	86	.6422
36	.8433	54	.7608	69	.7035	78	.6750	87	.6366

the instrument to remain in a vertical position when placed in the liquid in the vessel *a*. The upper bulb *b* is filled with air, and its volume is such that the whole instrument is lighter than an equal volume of water.

The stem is graduated in accordance to the Baumé scale, which is an arbitrary one. Some of the better grades of Baumé hydrometers have both the Baumé and the specific-gravity scales engraved on them, so that it is not necessary to consult a table. The reading on the neck at the point where it emerges from the surface of the liquid indicates on the Baumé scale the degrees, as they are called, or the heaviness, of the liquid.

The reading on the scale of the Baumé hydrometer for the heavier liquid has a lower numerical value than for the lighter liquid. The specific gravity, on the other hand, has a higher numerical value for the heavier liquid.

Kerosene.—Owing to the greater ease with which it may be vaporized, gasoline is practically the only fuel used in automobile engines. The use of *kerosene* is confined almost exclusively to internal-combustion engines of the stationary type. So far as their heating value per pound is concerned, there is not much choice between kerosene and gasoline, each developing about 19,800 B. T. U. per lb. Kerosene, however, is about 10% heavier, so that 1 gal. of kerosene has greater fuel value than 1 gal. of gasoline. Ordinary kerosene varies in specific gravity (at 59° F.) from .76 to .82. Exceptionally light kerosene, such as the Pennsylvania light oil, has a specific gravity below .76. On the Baumé scale, it varies from about 56° to 40°.

Alcohol.—While it is possible to use alcohol in an automobile engine, this is not done to any extent commercially in the United States, chiefly on account of its high price, even when denatured and thus not liable to an internal revenue tax. There are two kinds of alcohol: *methyl*, or *wood*, and *ethyl*, or *grain*, *alcohol*. Wood alcohol is not suitable for internal-combustion engines, although it may be used temporarily in an emergency.

Grain, or *ethyl*, *alcohol* has a specific gravity of .795, and may be obtained by distillation from corn, wheat, and other grains, potatoes, molasses, or anything containing sugar or starch. When pure it absorbs water rapidly from the air. As compared with gasoline as a fuel for internal-combustion engines, alcohol exhibits several striking peculiarities.

First, the combustion is much more likely to be complete. A mixture of 90° alcohol vapor and air will burn completely when the proportion varies from 1 of the vapor with 10 of air to 1 of the vapor with 25 of air, thus exhibiting a much wider range of proportions for combustibility than is the case with gasoline. As the combustion is complete, the exhaust is practically odorless, consisting only of water vapor and carbon dioxide.

Second, the inflammability of an alcohol mixture is much lower. This is due partly, no doubt, to the presence of water, which is vaporized with the alcohol in the engine and must be converted into steam at the expense of the combustion.

For these reasons, the compression of an alcohol mixture is carried far above that permissible with a gasoline mixture,

without danger of spontaneous ignition. The rapidity of combustion of alcohol in an engine is considerably less than that of a gasoline mixture.

Alcohol cannot be used economically in an engine designed for gasoline as a fuel; when used in such an engine, it will take about twice as much alcohol as gasoline to develop the same power. Neither can alcohol be successfully vaporized by carbureters designed for gasoline, because it is not so volatile as that fuel. In order that alcohol may be used economically, both the engine and the carbureter must be especially designed for this fuel.

There is nothing to prevent the use of alcohol in gasoline engines in emergencies, however; to do this it will usually be necessary to run the engine on gasoline until the carbureter and the engine are thoroughly warmed up. If the carbureter and the engine are cold, it will be extremely difficult to start the engine on alcohol; to facilitate starting on alcohol the carbureter will probably have to be heated by some convenient means.

Benzol.—The combustible liquid known as *benzol* is a by-product obtained in the manufacture of coke and illuminating gas; it is also produced by distillation from coal tar. The supply of benzol is very limited. Only about 3 gallons of it is obtained from every ton of coal converted into coke or used in gas making. At present, benzol is used in the United States only to a very limited extent in automobile work, as it can be procured in only a very few places.

Benzol is about the color of water; while it is not so volatile as gasoline, it is claimed that an internal-combustion engine fitted with an ordinary gasoline carbureter can be started practically as easily on benzol as on gasoline.

Vaporization of Liquid Fuels.—To produce combustion, combustible liquids must first be vaporized and their vapors mixed with air in suitable proportions. This process requires the addition of heat, which may be secured by absorption or by radiation from surrounding objects, and which will come mainly from the combustion itself after that has been started. Liquids that vaporize at ordinary temperatures are highly dangerous if their vapors are inflammable, and should

be handled with extreme care. If, like kerosene and the heavier oils, they do not vaporize at ordinary temperatures, they are not so dangerous. Alcohol, stanolind, benzol, and gasoline give off inflammable vapors at ordinary temperatures.

In automobile practice, the liquid fuel is vaporized before it enters the space where it is burned. The vaporization is accomplished by bringing the liquid into intimate contact with air. When the air and fuel vapor are thus mixed together in proper proportions, the mixture can be ignited and burned by the application of a lighted match, an electric spark, or any sufficiently hot substance, as a piece of red-hot metal.

The vapor of any of the liquids used as a motor fuel can be considered to be a gas so far as its use in the engine is concerned. In fact, illuminating gas is frequently made by mixing the vapor of gasoline with air, the proportion of the vapor being so great that the mixture will not burn until more air is added to it. This gasoline gas is carried through pipes and burned in the same manner as ordinary illuminating gas made from coal. Kerosene does not vaporize so readily as the other motor fuels, the application of heat being necessary to convert it into vapor and keep it in that state. Alcohol vaporizes less readily than gasoline, but far more readily than kerosene.

MIXTURES OF GASOLINE AND AIR

It will be well to bear in mind that gasoline is a name commercially applied to a rather wide range of combustible liquids, some of which are more accurately specified as naphtha, benzine, etc. The proportions of air and gasoline of any definite quality must be kept within a limited range in order to obtain the best results in the engine.

A given volume of air can absorb only a certain amount of gasoline vapor. A mixture containing less than this amount of vapor is neither a saturated nor a perfectly proportioned mixture; the less vapor it possesses, the leaner it is. A mixture containing more than this amount of vapor is not a perfectly proportioned mixture either; the more vapor it has the richer it is said to be. The proper mixture of gasoline and air, for explosive purposes in a gasoline-engine cylinder, burns, at atmospheric pressure, with a blue flame. Lean mixtures

behave in the same way, except that when they burn in a confined space the pressure produced is less than that produced by a perfect mixture. The surplus air does not burn; it is heated, however, and of course expands some. A more intense explosion will be produced by a proper amount of gasoline vapor and air if the two are first thoroughly mixed together.

If there is present in a mixture more gasoline vapor than the air present can take up, and the mixture is ignited, a certain amount of the vapor will be consumed, leaving the surplus unconsumed. Such a rich mixture burns under atmospheric pressure with a yellowish flame and leaves a sooty, or carbon, deposit. An intimate and uniform mixture is essential, and this should take place before the charge is fired. This means early and rapid evaporation, particularly at high engine speeds, and a certain amount of heat. United States government tests indicate that below an external temperature of about 60° there is an advantage in supplying artificial heat to counteract the cooling effect of the evaporative process. Heat should not be applied in excess of the requirements of the evaporative process, however, as this tends to reduce both the density of the charge and the maximum power of the engine.

As gasoline vapor is heavier than air, it tends to sink to the bottom of a vessel containing it, and unless agitated it mixes but slowly with the air above it. For this reason, a room in which gasoline vapor is present cannot be well ventilated by openings near the ceiling; but openings through the floor or under a door will allow the vapor to pass out.

GASOLINE SUPPLY TANK

The tank that carries the supply of liquid fuel for an automobile may be located either at a level considerably higher than the carbureter, so that the liquid will flow freely, or at a level lower than the carbureter, so that there will be no gravity flow to the latter even when the tank is full. When the tank is placed lower than the carbureter, either air or gas pressure must be used to force the liquid out of the tank and into the carbureter, or the fuel must be lifted automatically in some manner into a small supplementary fuel tank placed above the carbureter, whence it can flow into the latter by

gravity. The forcing of fuel to the carbureter from a tank on a lower level, usually at the rear, by means of pressure, such a tank being called a *compression tank*, was very common at one time, but as very few cars with compression tanks are still in use, a very brief description of the means used will be in order. In modern practice, a small air pump driven by the engine is used; this is so constructed as to deliver air into the tank at a pressure of approximately 2 lb. per sq. in. With this system a hand air pump is also supplied, for pumping up pressure on the gasoline after the tank has been filled, and also for emergency use when the engine air pump is disabled. A pressure relief valve is connected in the air line to prevent the pressure from rising above the desired limit.

All annoyances incidental to pressure feed from a tank at the rear end below the carbureter level are eliminated by the *vacuum-feed fuel system*, which is now fitted to the large majority of cars, and can be applied to most old cars having a tank below the carbureter level. The *Stewart vacuum tank*, shown in Fig. 2, is commonly employed in the vacuum fuel-feed system. Its operation is as follows: With the tank entirely empty, the float *o* has fallen to the position shown in Fig. 2, where the atmospheric valve *h* is closed and the vacuum valve *i* is open. If the engine is now cranked, either by means of the self-starter or by hand, and the throttle is closed, a partial vacuum is created in the intake manifold and hence also in the upper chamber *g*, the flap valve *n* being closed. Consequently, the pressure of the atmosphere on the fuel in the main supply tank forces fuel into the upper chamber *g*, through the pipe *k*. The float *o* is thereby raised, and also the levers *p* and *s*, the lever *u* being at rest, until the continued rising of the float brings the over-center spring *v* to the upper side of the fulcrum *t*, when this spring suddenly pulls up the lever *u*, thereby closing the vacuum valve *i* and opening the atmospheric valve *h*. Air then fills the upper part of the upper chamber and gasoline flows by gravity past the flap valve *n* into the lower chamber and to the carbureter. The float now falls and as soon as it has fallen far enough to bring the over-center spring *v* to the lower side of the fulcrum *t*, this spring suddenly pulls the lever *u* down, thereby closing

the atmospheric valve *h* and opening the vacuum valve *i*. Fuel now flows from the main supply tank into the upper chamber again, raises the float and finally closes the vacuum valve and opens the atmospheric valve again. The upper chamber thus alternately partly empties itself into the lower chamber and is filled again.

Should the vacuum tank, when empty, refuse to fill when the engine is cranked rapidly with the throttle closed, the probability is that some dirt has accumulated on the seat of the flap valve *n*. A pipe plug in the head of the tank, which is shown at *w*, Fig. 2, should then be removed and gasoline poured in through a small funnel; this gasoline will usually wash all dirt from the seat of the flap valve, and the tank will operate properly again, as soon as the pipe plug is replaced. If not, the tank must be taken apart and the flap valve cleaned. The joint between the body and head of the tank must be air-tight, a gasket shellacked on both sides being used to pack the joint.

A fuel tank above the carbureter level, such a tank being called a *gravity tank*, requires very little attention. There must always be a small opening in the upper portion of a gravity tank, so that air can pass into the tank as the fuel flows out; otherwise, a partial vacuum will be formed in the tank and the flow of fuel will gradually decrease until the carbureter does

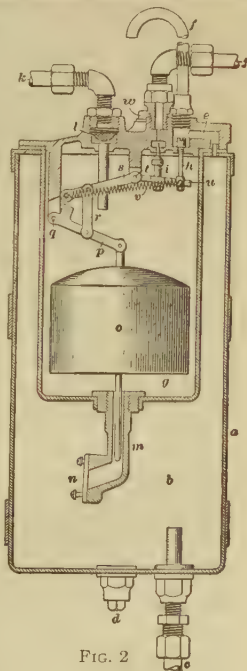


FIG. 2

not receive enough to keep the engine running. The smaller the air space in the upper part of the tank, the shorter is the time required for this to occur. Only a small hole is needed to allow the air to pass in; this hole is generally drilled through the filler cap of the tank. Gravity gasoline tanks are often placed under the front seats of touring cars, and at the rear of the front seats and as high up as possible on roadsters; in many cars of all types, however, the gasoline tank is placed in the cowl as high as possible.

A reserve compartment is provided in several makes of gasoline tanks. This compartment has a capacity of 1 gal. or more, and is so arranged that the gasoline will not flow out until a valve, which is ordinarily kept closed, is opened. Thus, after all the gasoline is used from the main part of the tank, there is still a reserve sufficient to carry the car to some source of supply. It is advisable to have this reserve tank so located that, when putting in a fresh supply of fuel, it will first enter the reserve tank and then overflow into the main compartment. In this way the gasoline in reserve is always fresh.

PRINCIPLES OF CARBURETER OPERATION

Definition.—A *carbureter* is an appliance for vaporizing liquid hydrocarbons by passing air either over the surface of or through the mass of the liquid, or by atomizing the liquid and mixing it with air.

Classification.—Carbureters may be divided into three classes, as follows: Those that use a large surface of the hydrocarbon and over which air is compelled to pass; these may be called *surface carbureters*. Those in which the liquid fuel is placed in a reservoir and the air is compelled to pass through the body of the liquid; these may be called *filtering carbureters*. Those that vaporize, or atomize, the hydrocarbon and inject it into a current of air; these are called *spray carbureters*. The first two types preceded the third in point of time, but the spray carbureters are now used exclusively.

Requirements for an Automobile Carbureter.—A successful automobile carbureter must fulfil the following requirements: It must give a practically uniform mixture, whether the demand on it is light or heavy, within the range of the speed actually

attained by the engine. It must not freeze up in cold weather. It must not be unduly sensitive to changes in the quality of the gasoline. It must not be seriously affected by changes in the level of the car. It must vaporize the gasoline reasonably well when starting in cold weather. It must operate equally well whether the engine has one or more cylinders. The quality of the mixture delivered must not be affected by the vibration of the car. The carbureter must not be exposed more than necessary to the entrance of dirt.

Principles of Spray Carbureters.—The spray carbureter has one or more nozzles with one or more small orifices; for convenience it will be assumed at first that the nozzle has only one. The air passing to the engine draws the gasoline out of the nozzle orifice in the form of spray, which vaporizes and mixes with the air, so as to form, under favorable conditions, a combustible mixture. In modern carbureters, the spray orifice is slightly above the constantly maintained level of the body of gasoline to which it connects.

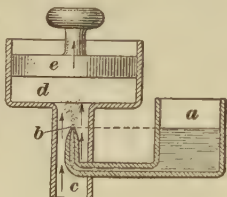


FIG. 3

Some of the elements of a spray carbureter are shown in Fig. 3. At *a* is shown the gasoline reservoir, and at *b*, the nozzle, which has an orifice that opens vertically upwards and is connected to the gasoline in the reservoir *a* by the passage shown. This passage is considerably larger in sectional area than the orifice. The nozzle is surrounded by a vertical tube *c*, which is open at the bottom and is connected at the top with a cylinder *d*, into which fits a free-moving piston *e*.

To illustrate the principle of operation, it will be assumed that the top of the nozzle *b* is at the same height as the surface of the gasoline in *a*. If the piston *e* is moved upwards, as indicated by the arrow on it, a partial vacuum will be created in the space surrounding the nozzle and a spray, or jet, of gasoline will be drawn out of the nozzle by suction, because the pressure against the liquid at the orifice is lower than the atmos-

pheric pressure on the surface of the liquid in the reservoir *a*.

Many of the modern carbureters use the *Venturi* tube in place of the straight air-inlet tube *c*, Fig. 3. The Venturi tube, as

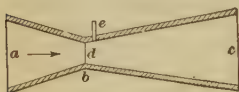


FIG. 4 (a)

shown diagrammatically in Fig. 4 (a), consists of two conical pipes joined at their small ends so as to form a continuous tube. A fluid entering at *a* and flowing in the direction of the arrow

passes through a rapidly narrowing part until it reaches the narrowest cross-section at *b*, known as the throat, and then passes through a gradually widening part to the discharge orifice at *c*. The Venturi tube possesses certain peculiar properties. Thus, when a fluid under constant pressure flows through a Venturi tube, its velocity of flow is greatest at the throat and least at the cross-section of greatest area; the amount of fluid discharged is much greater than that from a straight circular tube having a cross-section equal to that of the throat of the Venturi tube. The discharge of the Venturi tube may be twice, and even more than twice that of the straight tube, depending on the lengths of the tapering parts and their angles of convergence and divergence.

The reason for a greater velocity and discharge from a Venturi tube lies in the fact that a partial vacuum is formed at a point just beyond the throat, whereby the resistance to the flow is lessened. The existence of this vacuum could be shown experimentally by applying a vacuum gauge to the tube *e*.

The application of a Venturi tube to a carbureter tends to insure rapid vaporization and thorough mixing of the gasoline vapor with the air; the method of application is shown diagrammatically in Fig. 4 (b). The main air supply to the carbureter enters at *a*. The gasoline coming from its reservoir enters through the spray nozzle *e* placed centrally in the Venturi tube and just beyond the throat *b*. Owing to the partial vacuum existing at this point, the gasoline leaves the spray nozzle at a much higher velocity than would be the case otherwise. Furthermore, as is well known, the boiling point of a liquid



FIG. 4 (b)

becomes lower as the pressure is lowered, and by discharging the gasoline at a point where the pressure is below that of the atmosphere, it vaporizes faster. Then, the increased velocity of flow tends to produce a better spraying; the partial vacuum induces a better vaporizing. The result is a more intimate mixture of the gas and air than obtains otherwise.

Float-Feed Spray Carbureters.—The universally adopted method of maintaining a constant, or nearly constant, level of gasoline in the reservoir of the carbureter is by means of a float to which is attached a valve that cuts off the inflow of gasoline from the supply tank when the liquid rises to a predetermined level. The float is placed in the gasoline contained in the carbureter reservoir. This device is called a *float feed*. The float is adjusted to maintain a gasoline level slightly lower than the top of the nozzle. The average height of the spray nozzle above the normal gasoline level when the carbureter is level, as found in general automobile practice, is about $\frac{1}{8}$ in.

A float-feed carbureter in its most elementary form is shown in Fig. 5. This is not a presentation of an actual carbureter, but is introduced to make clear the principles involved. Gasoline enters the bottom of the carbureter at *a* and flows up past the valve *b* into the float chamber *c*, which is not perfectly air-tight above the float. Part of the gasoline flows into the passage leading to the spray nozzle *d*. As the gasoline rises in the float chamber it lifts the float *e* and also the valve *b*. When the gasoline reaches a level slightly below the top of the spray nozzle *d*, the valve *b* closes the inlet passage to the float chamber. The upper end of the chamber *h* is connected to the engine intake. The suction of the engine draws in the air at the opening *f* of the air passage *g*, past the nozzle *d*, with considerable velocity, into the mixing chamber *h* and out at the top thereof, as indicated by the arrows. On account of

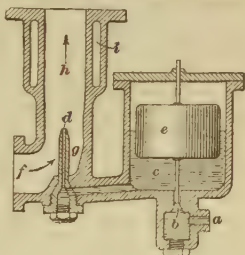


FIG. 5

the velocity of the air passing the nozzle *d*, and the pressure at *d*, which is lower than that upon the surface of the gasoline in the float chamber *c*, gasoline is drawn out from the spray nozzle; the float *e* therefore descends slightly by the lowering of the gasoline in the float chamber, and the float valve *b* is slightly opened, so as to allow more gasoline to enter and thus maintain a nearly constant level in the float chamber.

The vaporization of the gasoline requires heat, part of which is drawn from the walls of the air passage or mixing chamber *h*. This withdrawal of the heat leaves the metal around the air passage cold, even at times below the freezing point of water. The coldness retards the rapidity of vaporization, and hence interferes with the satisfactory operation of the carbureter. In order to obviate this, a jacket space *i* is sometimes provided around the mixing chamber, and water from the cylinder water-jacket may be circulated through this jacket space to keep the carbureter warm, or, a connection may be made to the exhaust pipe and part of the hot exhaust gases may be allowed to pass through the jacket.

The greatest problem in carburation is to design a carbureter so that it will give the proper and homogeneous mixture of fuel vapor and air required at all engine speeds and at all throttle openings. A float-feed carbureter of the elementary form shown in Fig. 5 cannot do this, because the flow of fuel from the fuel-nozzle orifice increases at a greater rate than the flow of air through the air tube when the engine is speeded up. In other words, if the ratio of fuel vapor to air is correct at a low engine speed, it will be too large at a higher speed, or, as it is commonly expressed, the mixture becomes *too rich*. This is just the opposite of the way the mixture should be; it will be most satisfactory if it is a little rich at very low engine speeds and becomes less rich as the engine speed increases. This statement about a carbureter of the elementary form shown in Fig. 5 must not be construed to mean that it is impossible to use a form so simple; its true meaning is that it will furnish a mixture substantially correct over only a rather narrow range of engine speed and throttle opening. Thus, if the nozzle and the air tube are correctly proportioned for an engine speed of 400 revolutions per minute, the carbureter will probably

deliver a substantially correct, although theoretically incorrect, mixture anywhere between perhaps 250 and 500 revolutions per minute.

The quantity of mixture flowing from the carbureter to the engine is governed by a hand-operated throttle valve, which is usually incorporated in the carbureter. Opening this valve allows more mixture to flow to the engine, which then increases its speed or power; conversely, closing the throttle valve cuts down the quantity of mixture flowing to the engine and hence slows it down or decreases its power.

Carbureter compensation may be accomplished, in general, in several ways: (1) By reducing the rate of fuel flow as the throttle opening increases; (2) by increasing the air supply as the throttle opening increases; (3) by combining a number of air tubes and fuel jets into a single carbureter; and (4) by a combination of methods 1 and 2.

There are a number of ways in which the first method of compensation may be accomplished. Among these may be mentioned a needle valve applied to the fuel nozzle to control the fuel flow and intended to be operated by hand by the operator from the driver's seat. An automatic compensation can, however, be effected by constructing the fuel nozzle or fuel jet in such a way that the ratio of fuel weight to air weight will either remain constant, or actually decrease instead of increase, at high motor speeds or large throttle openings; a fuel nozzle thus constructed is called a *compensating jet*.

The second method of compensation, which is accomplished by means of a valve applied to the air tube and controlled by hand from the driver's seat, was used to some extent in the early days of the automobile industry; however, it is open to the objection of requiring constant attention.

The third method of compensation, when worked out properly, will give an automatic compensating carbureter, which, while theoretically inexact in its compensation, will be sufficiently exact for all practical purposes.

The fourth method of compensation is employed in the majority of compensating carbureters. There are many ways in which compensation may be secured, most common among them being a weakening of the suction around the fuel nozzle

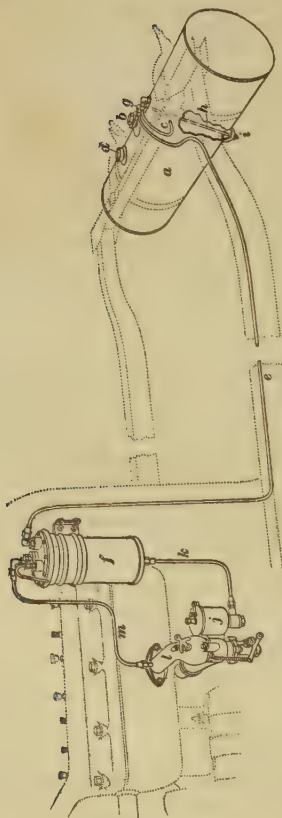


FIG. 6

at the higher motor speeds or larger throttle openings, generally by an inwardly opening valve that admits pure air directly to the mixing chamber, such a valve being called an *auxiliary air valve*. In another way, use is made of an air tube of which the cross-sectional area can be changed, thereby lessening the suction at the jet orifice at high motor speeds or large throttle openings. This retards the fuel flow from the nozzle without decreasing the volume of air passing through the air tube. In yet another way, the fuel flow is controlled by a tapered needle, called a *metering pin*, that is placed centrally in the orifice of the jet; by either moving this pin or the jet in the direction of its length the annular opening through which the fuel flows is either enlarged or restricted. This metering pin or the jet is moved by the motion of an air valve controlling the quantity of air pass-

ing through the air tube, by a mechanical interconnection to the throttle valve, or by the auxiliary air valve.

CARBURETER CONNECTIONS

In Fig. 6 is shown the main fuel tank, the Stewart vacuum-feed tank, the carbureter, and the necessary piping of a Dodge Brothers automobile in the positions actually occupied in the car. The main fuel tank *a* is made of pressed steel and is supported from the frame at the rear of the car. The tank has a filler cap *b* through which the fuel is placed in the tank, and has an air vent pipe *c* through which the tank is open to the atmosphere. A fuel gauge *d* shows the quantity of fuel in the tank. The fuel passes under the pressure of the atmosphere through the tube *e* to the top of the vacuum tank *f*; this tube *e* connects to the fuel tank elbow *g* and draws its fuel supply from the bottom of the tank *a* through the tube *h*, which dips partly down into the sediment bowl *i*. The object of drawing the fuel upwards out through the top of the tank is to prevent sediment being drawn into the tube *e*. The bottom of the vacuum tank *f* contains the fuel supply for the carbureter, which supply passes to the float chamber *j* through the tube *k*. The carbureter inlet *l* to the inlet valve passages, which in this case are inside the water-jacket of the engine, is connected by the vacuum tube *m* to the top of the vacuum tank. A fine brass-wire-gauze fuel strainer is incorporated in the vacuum tank, being placed directly below the outlet of the tube *e*. Further to insure that no sediment enters the carbureter, the tube *k* extends some distance above the bottom of the vacuum tank.

EXAMPLES OF CARBURETERS

Classification.—The carbureters in actual use at present, in accordance with their construction, may be divided as follows: (1) Carbureters without air valves of any kind; (2) carbureters with a single valve controlling the entire air supply, (3) carbureters with a single auxiliary air valve, (4) carbureters with multiple auxiliary air valves.

Some examples of the first class are the Zenith models, O, OD, and HN, and Stromberg, models L, LB, M, and MB. Examples of the second class are the Stewart and Kingston carbureters.

The third class of carbureters is probably most frequently

met with in practice; among these may be named models of the Stromberg, Schebler, Rayfield, Mayer, Cadillac, Franklin, and others. Examples of the fourth class are the Pierce-Arrow and models of Rayfield carbureters. It must not be surmised, however, that the carbureters here named are the only ones in use.

The carbureters described here have been selected solely to show clearly the salient features of the type they illustrate, but

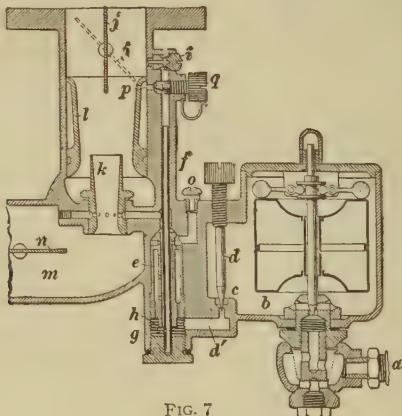


FIG. 7

their selection must not be taken as indicating a superiority over others of that type, and neither must the omission of any carburetor be taken to imply an inferiority in any way whatsoever.

Carbureters Without Air Valves.—The general construction of the Stromberg plain-tube carbureters, models L, LB, M, and MB, is shown diagrammatically in Fig. 7. Models L and M are of the vertical type and models LB and MB are of the horizontal type. The general principle of operation is the same in all four models, but the details of construction vary slightly.

The gasoline enters at *a*, Fig. 7, and passes into the float

chamber *b*, then through an orifice at *c* fitted with an adjustable needle valve *d* into the passage *d'*. This is fitted with a plug having a central hole and an annular chamber *e* called the *accelerating well*; the so-called *idling tube* *f* passes through the central hole of the accelerating well. The idling tube *f* receives gasoline through the small hole *g*; the accelerating well has three small holes drilled through its inner wall, a vent hole drilled through its upper end, and several small holes drilled through its lower end to communicate with the gasoline chamber *h* to which the fuel is supplied by the adjustable orifice *c*. The passage containing the idling tube *f* terminates at a plug *i* located above the throttle *j* when in its closed position. The small Venturi tube is shown at *k*, and the large one at *l*; both Venturi tubes receive a preheated air supply through the air tube *m* provided with a strangling valve *n* for enriching the mixture, for starting the engine in cold weather, by strangling the air supply. The liquid gasoline for the emulsion of gasoline and air supplied to the small Venturi tube *k* is drawn from the chamber *h* through the annular opening between the idling tube *f* and the hole in the plug containing the accelerating well *e*. The air-admission plug *o* supplies the air for the air-bled jets in the Venturi tube *k*; an air opening at *p* fitted with a low-speed needle valve *q* supplies air to the gasoline passing out through the idling, or low-speed, plug *i*.

The operation of the carbureters illustrated diagrammatically by Fig. 7 is as follows: When idling, the throttle *j* is closed. Under this condition, gasoline is drawn from the chamber *h*, through the idling tube *f*, and mixes with air from the passage *p*, the combustible mixture passing through the idling plug *i* into the space above the throttle and then to the engine. When idling, the two Venturi tubes *k*, *l* and the air-bled jets are out of action, and just enough air passes at a very low velocity through the Venturi tubes to supply that required for the idling mixture.

When the throttle *j* is opened slightly, the vacuum in the intake manifold of the engine is increased, and the air-bled jets come into action; for very low throttle positions the mixture is fed to the intake by both the idling jet *i* and

the air-bled jets. As the throttle is still further opened, the gasoline is drawn faster from the idling tube *f* than it can enter through the hole *g*, and consequently the idling jet automatically goes out of action, all the fuel now being supplied by the air-bled jets in the smaller Venturi tube *k*. The annular opening at *c* should be just large enough to keep the chamber *h* filled with gasoline at all motor speeds; this opening is regulated by trial by screwing the adjusting screw *d* up to strengthen the mixture and down to weaken it. The strength of the mixture for idling is adjusted by trial by means of the low-speed adjusting screw *q*, the throttle being fully closed for this.

To adjust the carbureter for idling, the engine is started with the low-speed adjustment screw *q*, Fig. 7, approximately one-half turn off its seat. When the engine has warmed up, the screw *q* is turned counter-clockwise until the engine idles steadily, which is usually when the screw *q* is somewhere between one-half and one and one-half turns off its seat.

The adjusting screw *d*, adjusts the mixture over the whole driving range; an approximate adjustment is obtained by turning it about three whole turns off its seat, which will probably give a rather rich mixture, and then screwing it in until trial shows a sufficiently weak mixture.

Carbureters With Single Air Valve.—One model of the Johnson carbureter is shown in Fig. 8. Other models embody the same principle of operation. For eight-cylinder engines they are fitted with a so-called *accelerator pump*, which is interconnected with the throttle valve and operates only when the throttle is quickly opened, temporarily enriching the mixture to give a rapid acceleration to the car.

Gasoline enters the carbureter at *a*, through a fine wire screen *b*. The gasoline enters the float chamber through the needle valve *c* and is maintained at a constant level by the cork float *d*, concentric with which is the spray nozzle *e* controlled by the hand-operated adjusting needle valve *f*. A strangling, or choke, tube *g* is directly above the spray nozzle and is so mounted that it can be partly rotated by the lever *h*. Ports leading from the air chamber *i*, which connects with the atmosphere by the air inlet *j*, are uncovered or covered by moving the lever *h*. Uncovering these ports allows air to

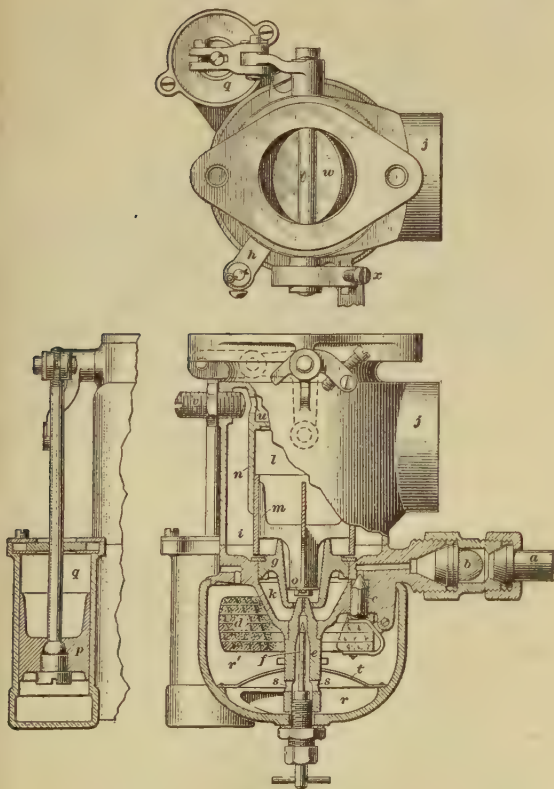


FIG. 8

pass from the chamber *i* to the passage *k*, through the bottom of the choke tube *g* around the spray-nozzle outlet, and up into the mixing chamber *l*. The circular air valve, or sleeve, *m* is free to slide vertically in the cylindrical guide *n*, and carries a circular lifter plate *o* at its bottom, directly above the top of the spray nozzle *e*. The strangling tube may be rotated by the choke lever *h*, but is confined vertically. The accelerating pump, or loosely fitting piston *p*, works in a cylinder *q*, which is open to the air at the top and connects at the bottom to the lower float chamber *r*, into which the spray nozzle opens by means of the cross hole *s*. A small passage in the diaphragm *t* connects the upper float chamber *r'* with the lower one *r*. A hole *u* admits air to the mixing chamber *l* from the air chamber *i*, the size of the opening being regulated by means of the low-speed adjusting screw *v*. The throttle valve *w* has the usual stop-screw *x* by which its closed position is regulated. To start the engine, the choke lever *h*, Fig. 8, is moved to close, partly or entirely, the ports through the edge of the choke tube *g*, leading to the passage *k*. Hence, when the engine is cranked, a very strong suction is exerted on the spray nozzle *e* producing a rich mixture in the cylinders. When the engine fires, the air ports of the strangling tube *g* are opened and the combustible mixture at idling speeds is supplied with air from the passage *k* and the hole *u*, the air sleeve *m* remaining seated. As the throttle is opened and the engine speeded up, the air sleeve *m*, and hence the lifter plate *o*, rises in proportion to the engine speed, and air enters through the annular opening between the bottom edge of the air sleeve *m* and the upper outer edge of the choke tube *g*. The opening between the circular lifter plate *o* and the hole of the choke tube *g* increases as the air sleeve *m* rises, whereby the suction on the spray nozzle *e* is kept such that the mixture of gasoline vapor and air is uniform at all speeds.

A sudden opening of the throttle valve depresses the piston *p* and creates a slight pressure in the lower float chamber *r*, forcing extra gasoline out of the spray nozzle *e* into the choke tube *g*, enriching the mixture and giving quick acceleration.

Adjustment of Johnson Carbureters.—First, the low-speed adjusting screw *v*, Fig. 8, and the needle valve *f* are screwed

in until they seat, and the stop-screw x is set for an almost closed throttle. The needle valve f is now opened about one and one-half turns and the engine started, enriching the mixture by the choke lever h .

When the engine has warmed up thoroughly, the spark is fully retarded and the throttle quickly opened; if there is no back-fire into the carbureter, the mixture is too rich, and the spray needle valve f is turned in about one-eighth turn. The operation is now repeated and the needle valve closed in until back-firing begins; the needle valve is then turned out about one-eighth of a turn to enrich the mixture slightly again. The carbureter is thereby adjusted for all intermediate and high speeds. Next adjust the throttle stop-screw x until the engine runs as slow as desired with the throttle closed. If it does not run smoothly the low-speed mixture is too rich and is weakened by turning the screw r out, a little at a time, until the engine fires evenly. If the idling speed increases the throttle stop-screw x is readjusted, and the low-speed screw r as well, if necessary.

Adjusting the carbureter with a retarded spark will give a mixture for intermediate and high speeds that is rich enough to give quick acceleration; a more economical setting is obtained, however, if the adjusting is done with the spark lever in the usual driving position.

In adjusting the carbureter it is important to have the choke lever h in its wide-open position, so it can be used afterwards for temporarily enriching the mixture.

Carbureters With Single Auxiliary Air Valve.—The *model R Schebler carbureter*, and also the *model T*, employ a single auxiliary air valve interconnected to a gasoline metering pin for obtaining a practically constant ratio of gasoline vapor to air. The *model T* carbureter is of the horizontal type and the *model R* of the vertical type.

An external view of a *model R Schebler carbureter* is presented in Fig. 9 (*a*), and a sectional view in (*b*). A constant level of gasoline is maintained in the float chamber a by the cork float b and needle valve c , the gasoline entering at d . The gasoline passes to the nozzle e through a passage f , the nozzle terminating at the throat of the Venturi tube g . The main air

intake *h* is usually connected by a flexible pipe to a stove around the exhaust pipe in order to obtain preheated air; the air passes from *h* through passages that cannot be seen in the illustration into the base of the Venturi tube *g*, through the Venturi tube, mixing there with gasoline vapor, and on into the mixing chamber *i*. At the higher engine speeds the auxiliary air valve *j* admits additional air to the mixing chamber; fluttering of the auxiliary air valve is prevented by the piston *k* fitting loosely in a dashpot cylinder *l* formed in the auxiliary air-valve cap *m*. This air valve is held up by a helical spring *n*, the tension of which can be adjusted by the screw *o*; the air valve bears down on the long end of the air-valve lever *p*, which is pivoted at *q* and carries at its other end the tapered metering pin *r* that enters the gasoline spray nozzle *e*. The throttle valve *s* is fitted with a throttle stop adjusting screw *t*, shown in view (a), for adjusting the idling speed of the engine; a strangling valve *u* is placed in the main air intake *h*. The pivot *q* of the air-valve lever *p* is mounted on an eccentric carrying the cam-lever *v* in such a manner that rocking the cam-lever will raise or lower the pivot *q*, thereby raising or lowering the metering pin *r*. The cam-lever *v* is connected by a wire to a dash or steering-post control, by the operation of which the combustible mixture can be temporarily enriched for starting and warming up of the engine.

There are two adjustments on the models R and T Schebler carbureters, one for gasoline and one for the auxiliary air valve. The gasoline adjustment is obtained by turning the auxiliary air-valve cap *m*, Fig. 9, to the right as far as it will go, and then turning it to the left one complete turn. The adjusting screw *o* is screwed in as far as it will go and then screwed out three or four complete turns. The engine is now started and allowed to run until thoroughly warmed up. With the engine idling and the spark retarded, the auxiliary air-valve cap is turned to the left one notch at a time until the engine fires perfectly when idling; turning the auxiliary air-valve cap to the left weakens the mixture by dropping the metering pin *r* farther into the spray nozzle *e*. This completes the gasoline adjustment. To make the air adjustment, the spark is well advanced and the throttle opened quickly; if the engine back-

fires into the carbureter it shows that the auxiliary air valve admits too much air, and the adjusting screw *o* must be screwed in a little at a time until back-firing ceases. The idling speed of the engine is adjusted by means of the throttle stop-screw *t*. All carbureter adjustments should be made with the dash control or steering-post control set to "Lean"; the mixture can then be temporarily enriched by this control without disturbing the carbureter adjustment.

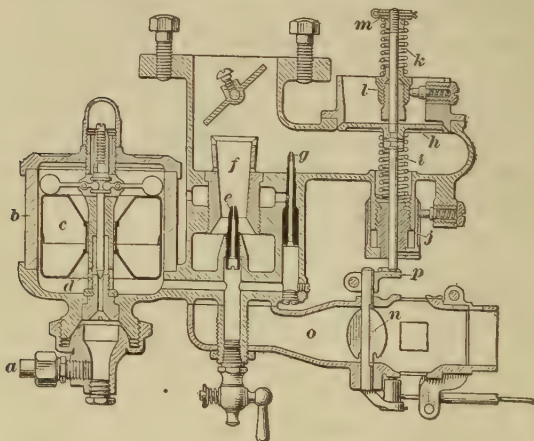


FIG. 10

These directions apply when the carbureter is completely out of adjustment; slight corrections can be made by turning the auxiliary air-valve cap to the right to enrich the mixture and to the left to weaken it. The spring-adjusting screw *o* will hardly ever need to be moved when once adjusted. The models *G*, *H*, *HA*, *HB*, *K*, and *KO* *Stromberg* carbureters all employ an auxiliary air valve.

The model *G* carbureter has two gasoline nozzles and greatly

resembles the model C excepting that the high-speed nozzle has no metering pin interconnected to the auxiliary air valve; it belongs to the vertical type and is not water-jacketed.

The models H, HA, and HB carbureters operate on the same principle and their method of adjustment is identical; the models H and HB are not water-jacketed and differ from each other in that the model H is vertical and the model HB horizontal. The model HA is water-jacketed. All three models have an auxiliary air valve controlled by a dashpot to prevent fluttering, and have the auxiliary air valve interconnected to a metering pin governing the opening of a high-speed gasoline nozzle.

The models K and KO have a single gasoline nozzle and a balanced air valve; both models are vertical and differ only in the position of the flange by which they are bolted to the intake manifold. In the model K this flange is in line with the carbureter and in the model KO the flange is at right angles to the carbureter.

A model G Stromberg carbureter is shown in section in Fig. 10. The gasoline enters at *a* and is maintained at a constant level in the glass float chamber *b* by a metallic float *c* and needle valve *d*. The low-speed spray nozzle *e* terminates at the throat of the Venturi tube *f*; the high-speed nozzle *g* opens into the mixing chamber. The auxiliary air valve *h* has below it the low-speed spring *i*, the tension of which can be adjusted by means of the low-speed adjusting nut *j*. The high-speed spring *k* is placed above the auxiliary air valve *h* and serves to limit the distance this valve can open, the high-speed adjusting nut *l* being used to regulate this distance. With the engine at rest, there is on an average a clearance of $\frac{1}{16}$ inch between the top of the high-speed spring *k* and the bottom of the air-valve cap nut *m*. A strangling valve *n* is placed in the main air intake *o*, which valve carries a cam *p* so adjusted that it will lock the air valve *h* to its seat when the strangling valve is closed by the dash or steering-post control; this permits an exceedingly rich mixture to be drawn into the cylinders when starting a cold engine. A flexible metallic tube leading to a hot-air stove is usually attached to the main air intake *o*.

The Stromberg model G carbureters have no gasoline adjustments, the correct size nozzles, numbered according to the

twist-drill gauge, being fitted at the factory. It is inadvisable to change the nozzles except upon the advice of a Stromberg service station or the carbureter makers.

To adjust the carbureter: With the engine at rest the low-speed nut *j*, Fig. 10, is turned until the air valve *h* seats lightly; then the high-speed nut *l* is set until there is about $\frac{1}{16}$ inch clearance between the spring *k* and the cap nut *m*. The engine is now started and run until thoroughly warmed up; then, with the engine idling, the low-speed nut *j* is turned right-handed until the engine slows down and then is turned left-handed about three notches, or until the engine runs strongly again. The throttle is now opened gradually and the spark advanced to the usual running position; if the engine back-fires into the carbureter, the high-speed nut is turned left-handed until all back-firing stops. If the engine fails to respond promptly to the opening of the throttle, it shows the mixture is slightly weak; this can be corrected by turning both adjusting nuts left-handed one or two notches. The idling speed is adjusted by means of the usual throttle stop-screw.

Carbureters With Multiple Auxiliary Air Valves.—The Rayfield carbureters, models G, L, GL, LL, M, and MR, all operate on the same general principle, and are of the type having two non-adjustable auxiliary air valves. The models G and GL are water-jacketed; the models G, GL, L, and LL are of the vertical type, and the models M and MR are of the horizontal type, for direct attachment to block-cast cylinders with integral intake passages. All of these newer model Rayfield carbureters are fitted with a secondary gasoline nozzle containing a metering pin, which comes into action only at high engine speeds.

A model GL Rayfield carbureter is shown in section in Fig. 11, and in perspective in Fig. 12; the same parts are lettered alike in both figures. The fuel enters the carbureter at *a* and passes through a removable wire-gauze screen *b* into the float chamber in which the float *c* and needle valve *d* maintain a constant gasoline level. The lower end of the fixed primary spray nozzle *e* is submerged in the gasoline. A tube *f* carries the gasoline to the dashpot chamber *g*, and by way of the passage *h* to the secondary gasoline nozzle *i*, which has a

variable annular opening the size of which is governed by the metering pin *j*. This metering pin moves up or down with the auxiliary air valve *k*, the lower end of which carries a piston *l* that is a loose fit in the dashpot chamber *g*. A passage *m* opens the top of the dashpot chamber to the atmosphere, so that the gasoline can flow freely into this chamber and keep it filled. The air valve *k* is held to its seat by the helical spring *n* the tension of which is correctly adjusted at the factory. An arm *o* is rigidly fastened to the auxiliary air valve and by means of a link *p* is attached to the butterfly valve *q*, which in the position shown closes the lower air entrance to the mixing chamber *r*, at the top of which the butterfly throttle valve *s* is located. The opening in the primary spray nozzle *e* is variable by means of the needle valve *t*, which is interconnected to the throttle valve in such a manner that opening the throttle raises the needle valve against the resistance of the spring *t'*. A constant air opening into the mixing chamber is drilled through the side of the carbureter as shown at *u*. The valve *t* is raised or lowered by an arm of the shaft *v*, which arm enters a slot cut into the side of the valve *t*. This shaft *v* passes through a bearing formed on the body of the carbureter, and to its outer end is pinned a bracket *v'*. Mounted loosely on the shaft *v* is a bell-crank whose arms are indicated by *w* and *w'*. The arm *w* carries the low-speed adjusting screw *x* that bears against a cam *x'* on the lower end of a vertical shaft that may be rotated in the bracket *v'* by means of the lever *x''* and dash adjustment wire *x₁*. The arm *w'* of the bell-crank carries a steel tongue *w₁* that bears against the curved surface of a steel block *y* the position of which in reference to the throttle-valve shaft can be slightly changed by means of the high-speed adjustment screw *z*.

With the engine at rest the two auxiliary air inlets are closed. To start the engine, the wire *x₁*, Fig. 12, is pulled out, which turns the cam *x'* and thereby lifts the needle valve *t* from the nozzle *e*, thus setting the carbureter temporarily for a rich mixture suitable for starting. If necessary, the carbureter is primed as well by pulling on the priming lever *c'*, which permits gasoline to overflow from the primary nozzle *e* into the mixing chamber. After the engine fires and as soon as it has

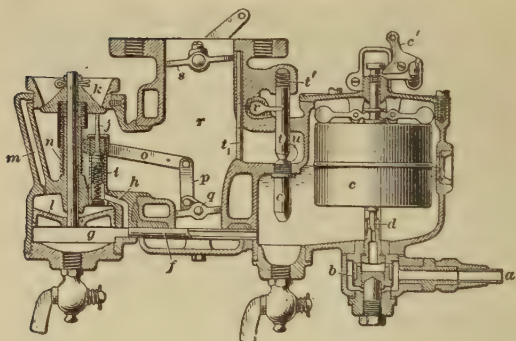


FIG. 11

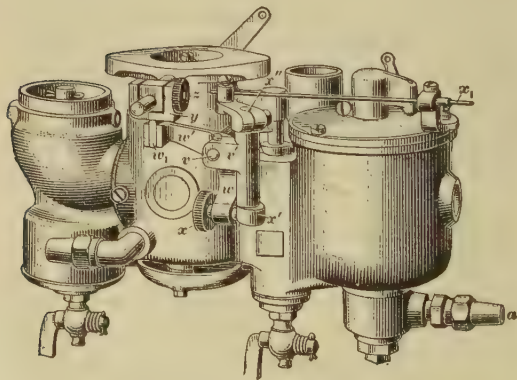


FIG. 12

warmed up, running idly, the wire x_1 is pushed in, thereby dropping the needle valve t and thus setting the carbureter for a leaner mixture. At idling speeds practically all air for the combustible mixture is drawn through the opening u , but at the higher engine speeds the two auxiliary air valves open in proportion to the engine speed. The opening of the throttle lifts the needle valve t , increasing the gasoline supply from the nozzle e ; the opening of the auxiliary air valve k pushes the tapered metering pin j down, opening the secondary gasoline nozzle i . The two nozzles, etc. are so proportioned as to maintain a practically constant ratio of gasoline to air at all engine speeds.

The dashpot piston l by offering a fixed resistance to the motion of the air valve k in either direction prevents any fluttering of the air valve, and thereby promotes a more homogeneous mixture of the gasoline and air in the mixing chamber. The small tube t_1 assists in getting a rich mixture above the throttle when the engine is idling.

The models M and MR Rayfield carbureters have a starting primer with a dash adjustment that permits liquid gasoline to be drawn from the float chamber directly to the engine cylinders.

The Rayfield carbureters, models G, GL, L, LL, M, and MR, have only a low-speed and a high-speed gasoline adjustment; turning the adjusting screws to the right enriches the mixture and turning them to the left weakens it. The low-speed adjustment must be completed first; the engine should be properly warmed up, and the dash control set for the weakest mixture.

To make the low-speed adjustment with the throttle closed and the dash control down, the adjustment screw x , Fig. 12, is turned slowly to the left until the steel tongue w_1 is just out of contact with the high-speed cam y ; the screw x is then turned to the right about three complete turns. The throttle is now opened slightly, the carbureter is primed by means of the lever c' , and the engine is started and thoroughly warmed up. The throttle is next closed until with a slightly retarded spark the engine runs slowly; the low-speed adjusting screw x is then turned slowly to the left until the engine slows down a little and is then turned to the right a notch at a time until

the engine idles smoothly. The idling speed is controlled by the usual throttle-arm stop-screw.

To make the high-speed adjustment, the spark is advanced somewhat and the throttle is quickly opened. If the engine back-fires into the carbureter when speeded up, the mixture is too weak, and must be enriched by turning the high-speed adjusting screw *z* to the right one notch at a time until there is no sign of back-firing when the throttle is opened quickly. If the engine chokes when the throttle is opened it indicates too rich a mixture, and the high-speed adjusting screw should be turned to the left until the engine begins to back-fire, and then to the right again until it runs satisfactorily at high speeds.

GENERAL DIRECTIONS FOR CARBURETER ADJUSTMENT

General Considerations.—In order that a person may be enabled to adjust any make of carbureter in the absence of the specific instructions furnished by the carbureter manufacturer, or given in the instruction book of the automobile, general directions are here presented. In applying these general directions to a concrete case, common sense must be used. Thus, if the carbureter is not supplied with an adjustable, compensating air valve, directions for adjusting this valve do not apply. Likewise, if the gasoline nozzle is not supplied with a needle valve, changes in the gasoline supply can only be effected by changing the size of the nozzle.

A carbureter may deliver either too rich a mixture or too weak a mixture at all speeds within the range of operation of the engine. More often, however, a mixture will be rich at certain speeds, high or low, and either normal or, possibly, too weak at other speeds; or it will be weak at high or low speeds and normal or too rich when the speed is changed.

1. A non-automatic carbureter will tend to take proportionally more gasoline at high than at low speeds. If adjusted correctly for low speeds, it will be wrong for high speeds, and vice versa; such carbureters are not used at present.

2. A stationary needle valve acting on the spray nozzle does not produce automatic regulation; it reduces or increases the gasoline feed in substantially the same ratio for all speeds.

3. A fixed shutter over the air intake does not produce automatic regulation. By partly closing it, the suction in the spray chamber is increased and the amount of air supplied is reduced, thereby increasing the richness while reducing the volume of the charge.

4. To obtain a uniform mixture with a carbureter, the gasoline feed at high speeds must be restricted, or the air must be allowed to enter more freely, to diminish the suction in the spray chamber. Some carbureters are arranged to by-pass a portion of the air around the spray chamber at high speeds. Sometimes the by-pass valve controlling this action is connected to and controlled by the throttle lever.

5. In an automatic compensating carbureter, opening the needle valve or reducing the main air-intake opening will give a richer mixture at all speeds.

6. In an automatic compensating carbureter, reducing the spring tension on the auxiliary, or diluting, air valve will permit this valve to open wider, especially at high speeds, and will therefore make the mixture weaker at high speeds. Increasing the spring tension on the auxiliary air valve makes the mixture richer at high speeds.

7. A weaker mixture may be obtained at low speeds by increasing the spring tension on the automatic or auxiliary valve and enlarging the main air intake; or it may be obtained by increasing the spring tension and partly closing the spray nozzle needle valve. The latter arrangement will not give as full charges as the other, as the resistance to the ingoing charge will be greater; but if the carbureter is large for the engine, it may give better vaporization on account of the higher air velocity past the spray nozzle.

8. If, at high speed, richer charges are desired, the throttling effect or reduction of air supply due to increasing the spring tension on the automatic valve may be offset by increasing the opening of the main air intake so as to increase the velocity of the air flowing past the nozzle and thus draw therefrom an increased quantity of fuel. The spray-nozzle needle valve also should be opened farther. At low speeds, the increased openings of the main intake and the needle valve will neutralize each other as regards the proportions of the mixture.

9. If the automatic valve is provided with a stop, its effect will be to render the carbureter non-automatic at speeds above those at which the automatic valve comes against the stop. For this reason, reliance should be placed on the spring where possible, rather than on the stop. The chief function of the stop should be to prevent the valve from opening under sudden pulsations so far that, by reason of its inertia, it cannot close promptly.

10. A slightly weak mixture burns faster than a normal or a rich mixture; this, therefore, is the best mixture for high speeds. When, however, the engine is working under a heavy load, a slow-burning mixture is better, as it maintains a higher pressure on the working stroke. The ideal carbureter adjustment, therefore, should give a normal mixture, or one very slightly rich, at the slowest speeds, and a weaker mixture at high speeds.

11. Occasionally a change in carbureter adjustment is made necessary by a change in weather or in the quality of the fuel. Such changes are properly made in the main air or needle-valve openings, as the changes must be the same for all speeds.

12. In order to have correct adjustment, the gasoline level in the float chamber must be at the spray orifice or slightly below it.

Adjusting Carbureter in Garage.—The method of adjusting a spray-nozzle carbureter with auxiliary air valve and with a spray-nozzle needle valve is as follows, assuming that the carbureter is completely out of adjustment:

Set the automatic air-valve spring about midway between the extremes of its adjustments. Open the valve between the fuel tank and the carbureter, and open the spray-nozzle valve a half of a turn, or so. Prime the carbureter until the gasoline drips from it, if it is of such a form that surplus gasoline flowing from the spray nozzle runs readily from the carbureter. If the carbureter is of a type that retains the overflow from the spray nozzle, note whether the float chamber of the carbureter fills promptly after the fuel-tank valve is opened. Set the spark lever in late position, and then crank the engine.

If the engine makes only a few revolutions and stops, open the needle valve slightly more, prime the carbureter, and crank

the engine again. Continue these operations, setting the needle valve of the spray nozzle more open or more closed, until the engine continues to run. Note whether sooty smoke comes from the exhaust. If it does, the mixture is too rich. The black smoke of the exhaust should not be confused with the blue or bluish-white smoke that arises from too much lubricating oil in the engine cylinder. The blue smoke hangs in the air, but the black smoke is generally visible only as it escapes from the exhaust pipe, or muffler. Close the needle valve accordingly, a little at a time, until the black smoke disappears. The engine should be allowed to run a little while after each adjustment of the needle valve, in order to allow it to come to a constant condition of operation. There may be explosions in the muffler during the time that black smoke is coming from the exhaust. An overrich mixture often fails to ignite; the unburned mixture then passes out with the gases, and, in mixing with air in the muffler, becomes a combustible mixture that may be ignited by the next exhaust of a burning charge, thus causing an explosion in the muffler. Muffler explosions also occur on account of a faulty ignition system. They are generally quite heavy and loud.

Again, if the engine continues to run, but there is back-firing into the intake pipe and carbureter, the mixture is too lean. The explosions in the intake due to back-firing are not so loud as those in the exhaust and muffler. In case of carbureter explosions, open the needle valve of the carbureter gradually until back-firing stops. Next, close the throttle until the engine runs slowly, and then open it quickly to see whether the engine responds to the open throttle by promptly increasing speed. If the engine back-fires when the throttle is opened, thus indicating a lean mixture, the air-valve spring should be tightened so as to press harder on the automatic valve; but if black smoke appears when the throttle is opened, the air-valve spring should be set for less pressure. Tightening the air-valve spring gives a mixture that is proportionately richer on open throttle; relieving the spring tends to make a mixture that is richer when the throttle is only slightly opened.

Adjusting Carbureter on Road.—The next step is to try the car on the road. This can generally be done most satisfactorily

on a slightly ascending grade; but the rate at which the car speeds up on the level road will also test the adjustment of the carbureter. When making adjustments on the road, the general method given for the preliminary test can be followed. In general, the adjustment can be made quickest by giving the air valve different settings and then testing the needle valve throughout the range that appears necessary to obtain the best power without changing the setting of the air valve. The air valve can then be adjusted again, and the same process repeated with regard to the needle valve.

It should be borne in mind that the setting of the carbureter that gives the best results in a garage where the temperature is approximately that of a living room, and the engine is running light, that is, without load, will not generally be the best when the car is taken out on the road, especially if the outdoor temperature is greatly different from that in the garage. To a less marked extent, the adjustment of the carbureter is affected by differences of moisture in the air in the garage and that outside. The travel of the car may also affect the mixture.

PREHEATING OF CARBURETER AIR SUPPLY

Necessity for Preheating Air.—The gasoline delivered from the nozzle of a carbureter is in the form of a mist or spray, and the fineness of the particles depends largely on the effectiveness of the nozzle. When the spray produced is very fine and the air supply has a temperature of 60° F. or greater, the gasoline will vaporize readily and a good mixture will be formed. But as the temperature of the air is frequently much below 60° F., to insure perfect vaporization it becomes necessary to supply heat from an external source. Sometimes the vaporizing chamber is water-jacketed, but another common method is to draw the air supply over the exhaust pipe from the engine. A part of the heat in the exhaust gases is thus transmitted to the air supply and is carried by the latter into the carbureter, thus insuring rapid vaporization.

Heating Air by Exhaust Gases.—A method of preheating the air supply to the carbureter by using the hot gases exhausted from the engine is shown in Fig. 13 (a) and (b). Around the exhaust pipe *a* is fitted a short sleeve *b*, the inside diameter of

which is considerably greater than the outside diameter of the exhaust pipe. As the sleeve is held away from the pipe all around by the lugs *c*, a space is formed inside the sleeve. A pipe *d* connects the sleeve to the main air intake of the carbureter. The suction in the carbureter draws air between the

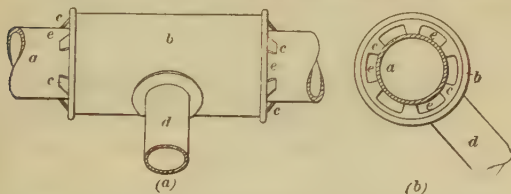


FIG. 13

sleeve and the exhaust pipe through the openings *e*, and this air is heated by direct contact with the hot exhaust pipe. It then flows through the pipe *d* to the carbureter, where the heat it has absorbed is utilized in producing more thorough vaporization of the gasoline spray.

HEATING OF MIXTURE

The gasoline available today cannot be completely vaporized even by mixing it with air heated to as high a temperature as practical considerations permit in automobile work, as some of the heavier hydrocarbons in it have a temperature of vaporization considerably beyond that of the heated air. This fact has led to the design of exhaust-heated intake manifolds, combined intake and exhaust manifolds, and hot-spot manifolds, the idea being to apply as much heat as possible to the incoming fresh charge to insure a more complete vaporization of the gasoline, thereby securing better fuel economy. In combined intake and exhaust manifolds the intake part of the manifold is heated to a fairly high temperature by the exhaust part, thereby heating the fresh charges passing through the intake part. Combined intake and exhaust manifolds are also built for a large number of engines fitted originally with

separate manifolds, by several concerns specializing on this line of work.

Fig. 14 (a) shows the external appearance of a combined intake and exhaust manifold used on a six-cylinder engine built for the trade by the Lewis Motor Corporation, Detroit, Michigan. The lower part of the manifold forms the intake, which communicates with the several intake ports of the cylinder casting; the carbureter is attached at *a*. The upper

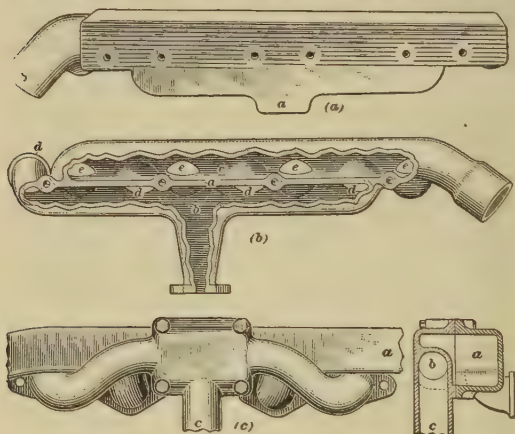


FIG. 14

part receives the exhaust from the cylinders, the exhaust pipe leading to the muffler being attached at *b*. There is an internal division wall, cast integral with the manifold, between the intake and exhaust parts. Such a division wall can be clearly seen at *a* in view (b), which is a combined intake and exhaust manifold sold under the trade name "Wilmo," and manufactured by the Whittier Company, Chicago, Illinois, to fit the engines of a large number of cars. In view (b) part of the outer wall is broken away, in order to show clearly the intake

part *b*, the exhaust part *c*, the intake ports *d*, and the exhaust ports *e*.

Fig. 14 (*c*) shows a *hot spot* intake manifold as used on United States Army trucks and also on a number of passenger cars. The hot exhaust gases of the exhaust manifold *a* sweep over the upper wall *b* of the intake manifold *c*, thereby vaporizing the gasoline.

TRANSMISSION AND CONTROL SYSTEM

CLUTCHES

Purpose.—In an automobile driven by an internal combustion engine, means must be provided for connecting the engine to the transmission gearing, as such an engine cannot be started under full load. For this purpose a *friction* clutch is employed. Friction clutches used in automobiles may be broadly divided into two general types, namely, *cone clutches* and *disk clutches*.

Cone Clutches.—A single-spring cone clutch is shown in place in the flywheel, in cross-section, in Fig. 1 (*a*), and in end view in (*b*). Parts of the same clutch are illustrated in perspective in Fig. 2, and both illustrations should be referred to in reading the description. The internal cone *a* is free to slide lengthwise and also to rotate on the rear end *b* of the crank-shaft, and a sliding connection to the transmission shaft (not shown) is made by a squared hole in the rear end of the clutch-spring casing *c*, which is bolted to the hub of the internal cone *a* and encloses the clutch-closing spring *d*. The squared hole in the clutch-spring casing fits over the squared forward end of the main transmission shaft when the clutch is assembled in place. In many unit power plants the connection between the internal cone and the transmission is made by *splines*, which are keys cut from the solid material. In cases where the transmission is entirely separate from the engine, connection from the internal clutch cone either to the transmission or to the propeller shaft is made by one or two universal joints, to allow for disalignment between the engine and propeller shaft or transmission.

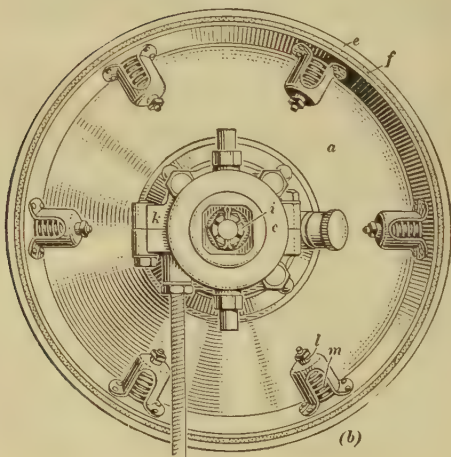
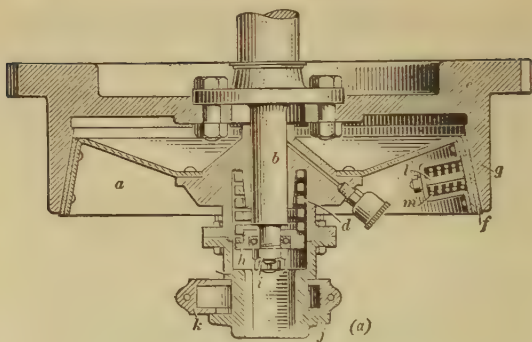


FIG. 1

The external cone in the rear of the engine flywheel *e*, Figs. 1 and 2, rotates with the crank-shaft. When the outside surface *f* of the inside cone is in firm contact with the inside surface *g* of the outside cone, the clutch as a whole is said to be *in engagement*, and is so shown in the three views presented in Figs. 1 and 2. If the outside cone is rotating, it will carry the inside cone around and thereby cause it to transmit the turning effort (the force exerted), or *torque*, of the engine to the driving wheels when the transmission gears are engaged. The force with which the inside cone is driven depends on the pressure and the friction between the conical clutch surfaces. On account of these friction surfaces being conical, there is a wedge-like action that gives a pressure much greater than the force with which the inside cone is pressed against the driving, or outside, cone. The proper inclination of the conical friction surfaces to permit firm gripping and reasonably prompt releasing averages about 12 degrees to the center line, as shown in Fig. 1.

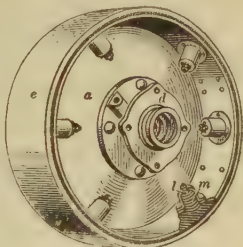


FIG. 2

In the cone clutch shown in Figs. 1 and 2, the closing spring *d* is confined under compression between the hub of the inside cone and the clutch thrust bearing *h*, Fig. 1 (*a*), which thrust bearing is on the extension *b* of the crank-shaft and is confined lengthwise by the clutch-spring adjusting nut *i*. This closing spring presses the inside cone into the outside cone.

To disengage the clutch, the inside cone is withdrawn from the outside cone against the pressure of the clutch-closing spring; a collar *j*, Fig. 1, is formed on the clutch-spring casing, against which the clutch collar *k* is pressed when the clutch pedal of the car is pushed forwards. The collar *k* is thereby forced toward the rear of the car, carrying the clutch-spring casing *c* and hence the inside cone *a* with it, thus leaving the flywheel free to rotate without driving the inside clutch mem-

ber. In other words, the engine is now entirely disengaged from the transmission and hence from the car. In connection with this it should be understood that, with the transmission gears in neutral and the clutch engaged, the engine is also disconnected from the car.

Various methods of obtaining a smooth engagement of the cone clutch are in use. A very common method is shown in Figs. 1 and 2. Plungers *l* are set into the metal of the cone and are forced out by expansion springs *m* against the inner side of the leather, the outward motion being limited by a cotter pin or nut in the stem of each plunger. This presses out the part of the leather that is over the end of the plunger, so that it stands higher than the other parts of the leather facing. Several of these plungers are used in the complete cone as shown. When such a clutch is brought into engagement, the high portions of the leather facing first come into contact with the external cone; thus, the pressure against the leather is limited to the expansive force of the springs *m*. The clutch, therefore, does not grip suddenly and jerk.

Sometimes flat springs slightly bent to a bow shape are placed under the clutch leather, while in other cases, cork inserts are placed in the leather with their faces protruding a little beyond the surface of the leather.

Disk Clutches.—Multiple disk and plate clutches may be divided into *dry-plate clutches* and *oiled clutches*. Oiled clutches are inclosed in oil-tight cases and run in a bath of oil.

In the dry-plate clutch lubrication is made unnecessary either by facing one set of disks with asbestos fabric on both sides or by making use of cork inserts. Both of these materials have good frictional qualities when used on steel. The asbestos fabric is composed of asbestos fiber and woven wire and is riveted to the plates. The asbestos is used on account of its good frictional qualities and its resistance to heat, while the wire is used to give the asbestos the necessary strength. Cork inserts in disk clutches serve the same purpose as in cone clutches; that is, they provide a means for obtaining a smooth and gradual engagement.

One form of multiple-disk dry-plate clutch is shown in Fig. 3 in cross-section. There are four driving disks *a* mounted on sev-

eral circular studs *b* fastened to the flywheel *c*, and there are three separate driven disks *d*, which together with the clutch spider or clutch front pressure plate *e* and clutch rear pressure plate *f*

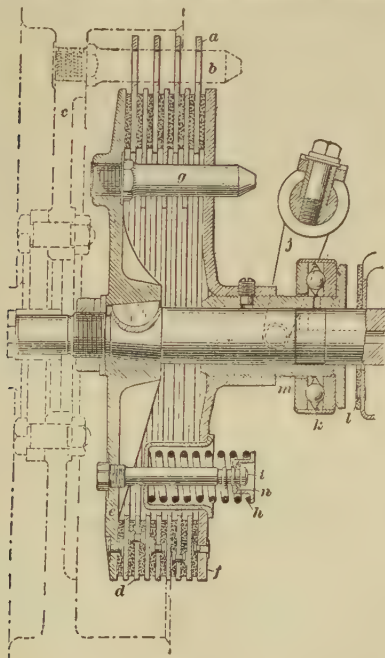


FIG. 3

are faced with friction fabric riveted on. The plates *e* and *f* and the disks *d*, etc. form the driven part of the clutch. The driven disks are mounted on studs *g* fastened to the plate *e*,

which studs pass loosely through the plate *f*. All disks are normally pressed firmly together by several springs *h* mounted on clutch spring studs *i* fastened to the plate *e*. When the clutch pedal is pressed forwards, the plate *f* is drawn rearwards and the clutch is released. When the clutch pedal is pressed fully forward the clutch brake *l* slows down the driven clutch member.

In this particular design of clutch the tension of the clutch springs can be adjusted by changing the position of the clutch-spring collars *n* on the clutch-spring studs *i*. These studs are grooved as shown and a lock in the form of a horseshoe is dropped into one of the grooves to retain each collar *n*.

The steel which is used to a considerable extent in the manufacture of disks of all metal friction clutches is *saw-blade steel*.

CLUTCH BRAKES

In order to eliminate noise as far as possible when changing gears from a low to a higher speed, *clutch brakes* are used extensively in modern cars.

The transmission gears that are to be meshed when changing speeds must have practically the same circumferential velocities in order to make possible a silent shift; hence, for different conditions the brake must be used in different ways. When starting the car, the driven gears of the transmission are at rest; therefore, the clutch pedal should be fully depressed so as to apply the clutch brake fully and bring the driven member of the clutch and the driving gears of the transmission also at rest.

When changing from a low to a higher gear, the driven gear of the transmission is running slower than the driving gear that is to be meshed with it; hence, it is necessary to slow down the driving gear but not to stop it entirely. This is done by releasing the clutch but not fully depressing the pedal, or, in other words, by partly bringing the clutch brake into operation.

When changing gears from a higher to a lower speed, the clutch pedal should be operated so as not to bring the clutch brake into action, because during this operation the speed of the driving gear of the transmission is less than that of the driven gear and any application of the clutch brake will decrease it still further. The speed of the driven member of the clutch

and of the driving gear of the transmission can then be allowed to increase with the engine speed while the gears are in neutral until practically equal circumferential velocities of the meshing gears are obtained.

SPEED-CHANGING GEARS

Purpose.—While great speed changes of an automobile can be obtained by means of the throttle and spark, there are limits to the changes that can be made by these means, and when these limits are reached, it is necessary to change the gear ratio between the engine and the driving wheels. The device used for this purpose is properly called a *change-speed gear*, but, popularly, it is known as a *transmission*. As the gasoline engine applied to automobiles is irreversible, it is necessary, in order to go backwards, to change the direction of rotation of the driving wheels by bringing into action a set of gear-wheels that will do this. This set of gear-wheels is called the *reversing gear*, or *reverse* for short, and in all modern transmissions is incorporated in the change-speed gear.

Omitting obsolete forms, change-speed gears may be divided into three general classes, namely, *sliding change-speed gears*, *planetary change-speed gears*, and *friction gears*. Sliding change-speed gears are either progressive or selective. In a *progressive transmission*, it is necessary to pass from first speed to second speed to third speed; in a *selective transmission* it is possible to pass at once from one speed to any other that is selected.

While progressive transmissions were quite popular at one time, they are not fitted to modern cars; only selective and planetary gear transmissions are in use, and a few friction transmissions.

Selective Transmissions.—In the sliding-gear transmission, spur gears are carried on two parallel shafts; one of these is in two parts, a forward, or driving, part and a rearward, or driven, part; the other shaft is a *countershaft*, or *jack-shaft*, through which the power is transmitted for certain speeds. The various speeds are obtained by sliding the gears axially on the main shaft and securing the desired speed ratio by bringing them in mesh with the proper gears on the countershaft. For what is known as the *direct drive*, the two parts of the main trans-

mission shaft are locked together, forming a direct drive from the engine to the rear axle. Sliding-gear transmissions are ordinarily designed to give either three speeds forwards and one reverse, or four speeds forwards and one reverse. The former is popularly called a *three-speed transmission*, and the latter a *four-speed transmission*.

There are two types of selective transmissions, namely, the *horizontal* and the *vertical*. In the so-called horizontal transmission, the two shafts on which the change-speed gears are

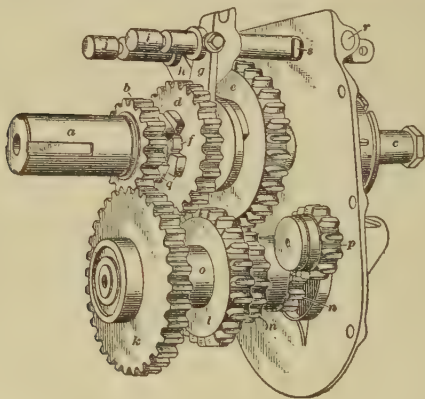


FIG. 4

mounted lie in the same horizontal plane, while with the vertical transmission the shafts lie in a vertical plane, one above the other.

The most widely used transmission system for pleasure cars is the three-speed transmission of the selective type. An example of a vertical three-speed transmission used in unit power plants is shown, removed from its casing, in Fig. 4. In this system the countershaft is mounted below the main shaft. The main shaft consists of the driving part *a*, which carries the

pinion *b*, and the driven part *c*, which carries the sliding gears *d* and *e*, and which rotates in a roller bearing mounted within the pinion *b*, and another antifriction bearing at its rear end. The gears *d* and *e* are free to slide axially on the shaft *c*, but are prevented from revolving on it by splines *f* that fit into corresponding slots in the hubs of the gears. The sliding of the gears is accomplished by the *shifter forks* *g* and *h*, which are operated by the change-speed lever acting through the *shifter rods* *i* and *j*, respectively. The gears *k*, *l*, *m*, and *n* are fixed to the countershaft *o* and revolve with it. The idler gear *p* is carried on a short shaft of its own and is brought into use for obtaining the reverse motion. The pinion *b* and the gear *k* are constantly in mesh; hence, the countershaft always revolves when the shaft *a* is in motion. The driving shaft *a* is connected to the driven side of the friction clutch and receives its power from the engine, while the driven shaft *c* is connected to the propeller shaft and drives the differential gear and rear wheels.

First, or *low*, *speed* is obtained by shifting the gear *e* by means of the rod *j* and the fork *h* until it meshes with the gear *m* on the countershaft, as shown in Fig. 4.

Second, or *intermediate*, *speed* is obtained by unmeshing gears *m* and *e* and shifting the gear *d* in mesh with the gear *l* on the countershaft.

In the *third*, or *high-speed*, position the drive is direct from the shaft *a* to the shaft *c* without going through the intermediate gears on the countershaft. This setting is accomplished by sliding the gear *d* forwards so that the clutch jaws *q* at the front end of the gear engage with those on the rear end of the pinion *b*. The transmission of power is now direct from the driving shaft *a* through the jaw clutch to the driven shaft *c*. The pinion *b* is still in mesh with the gear *k*, so that the countershaft revolves, but no power is transmitted through it because the gears *l*, *m*, and *p* run freely without meshing with either gear *d* or *e*.

To obtain the *reverse*, the gear *e* is shifted to mesh with the idler pinion *p* and the gear *d* is shifted to a position midway between *k* and *l*. Power is transmitted to the countershaft by means of the pinion *b* and the gear *k*, and through the shaft to the gear *n*, which meshes with the pinion *p*. The gear *n* is

small enough in diameter to clear the gear *e*; it drives the gear *e* by means of the idler *p*. The introduction of this idler causes the gear *e* to revolve in the same direction as the gear *n*, which direction is opposite to that of the shaft *a* and the driving pinion *b*. In all the other cases that have been considered, the driving shaft *a* and the driven shaft *c* rotate in the same direction for forward travel of the car.

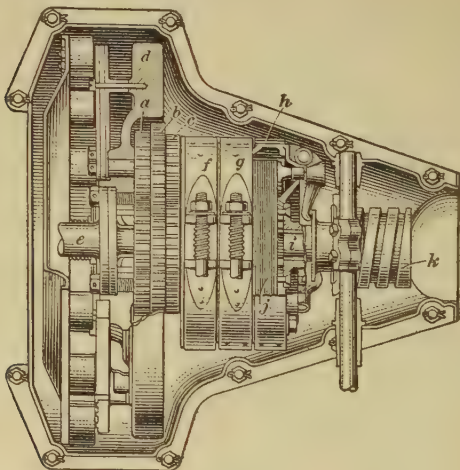


FIG. 5

To obtain the *neutral position*, the gear *e* is shifted to a position midway between the gears *m* and *p*, and the gear *d* is shifted to a position midway between the gears *k* and *l*.

In order to secure accurate meshing of the gears as well as to hold them in position, the shifting bars for selective change-speed gears are provided with a locking device. This device usually consists of a spring-operated plunger that drops

into a slot in the shifting bar for each position of engagement of the gears. In Fig. 4, the plunger operating on the shifting bar *i* is located beneath the plug *r* in the end member of the housing and when the gears are shifted to neutral or any other regular position, it drops into a **V** slot *s* in the bar *i*.

Planetary Transmission.—The transmission used in the Ford automobile, shown in Fig. 5, serves the combined purpose of a clutch and a transmission. The transmission is of the planetary type and gives two speeds forwards and one in reverse. There are three sets of three gears each, of which gears *a*, *b*, and *c* form one group, placed around a central spindle. These clusters of gears are mounted in the flywheel *d* and each gear meshes with one of three gears, not shown, that turn around an extension of the engine shaft *e* but are not fastened to it. Each of the central gears is part of one of three sleeves, the opposite end of which is fastened to one of the three drums *f*, *g*, and *h*. Drum *h* is also fastened to the propeller shaft, the end of which is shown at *i*. Each of the three drums is surrounded by a band brake. The gears are so proportioned that the propeller shaft will be driven at slow speed when the brake is applied to drum *g* and the motion of the propeller shaft will be reversed when the brake is applied to drum *f*. Applying the brake to drum *h* retards the motion of the car. The high speed ahead is obtained by means of the disk clutch *j*, which locks the shafts *e* and *i* together, thus giving a direct drive. The clutch is held in engagement by the spring *k*, which must be compressed in order to release the clutch.

Friction-Gear Transmission.—The simplest transmission that can be applied to an automobile is the *friction transmission*, of which a typical example is illustrated in Fig. 6. In this transmission, the engine *a* is permanently attached to a disk *b*. A friction wheel *c* is mounted on a shaft *d* so that it can be made to move across the face of the disk *b* and drive the shaft *d*. The friction wheel *c* is shifted by a bell-crank *e* connected to a crank *f* of the control lever *g*, the bell-crank being pivoted to the frame at *h*. The bearings of the shaft *d* are attached to the side members of the chassis in such a manner that by pressure on the foot-pedal *i* the bearings, and hence the friction wheel *c*, can be

brought forwards into engagement with the disk *b*, when it will be driven by friction. The rotative speed of the friction wheel depends on its distance from the center of the disk *b*. Thus, to obtain a slow speed, the friction wheel *c* is shifted toward the center of the disk *b* by means of the control lever *g*; and to obtain higher speeds, it is shifted toward the periphery. To obtain a reverse, the friction wheel is shifted past the center of the disk *b*; then, when brought into engagement, it will drive the car backwards.

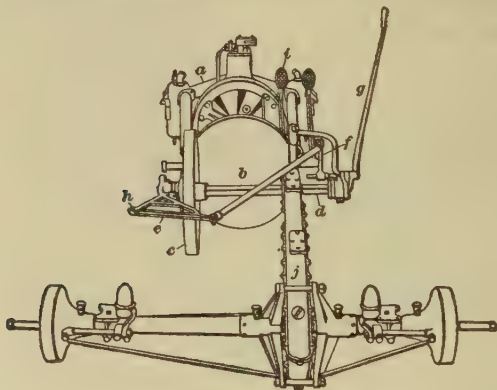


FIG. 6

Electric Transmission.—The Entz electric transmission, in place in the chassis of an Owen Magnetic car, is shown in Fig. 7 in diagrammatic form. The transmission consists chiefly of an electric generator having a revolving field *a* forming the flywheel of the engine, and an electric motor having a stationary field *b*. The generator armature *c* and motor armature *d* are both fastened to the armature shaft *e*, which shaft, through a universal joint *f*, is connected to the propeller shaft *g*. There is no mechanical connection whatsoever between the engine and the driving wheels of the car, either when the car is standing

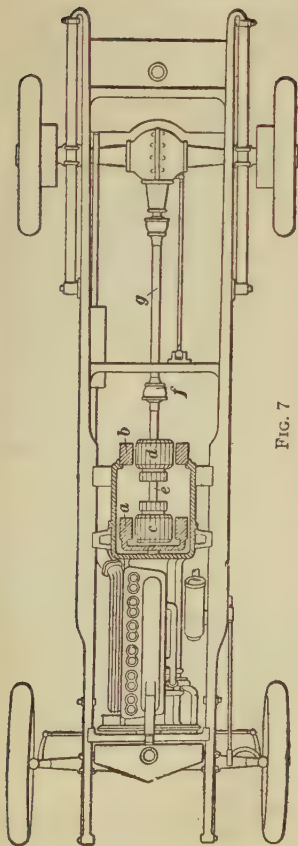


FIG. 7

or running. Part of the electric transmission is a series of a resistance coil and a suitable switch; a storage battery is also fitted.

To crank the engine, storage-battery current is turned into the generator, which now acts as a motor and spins the engine. As soon as the engine fires, the switch is either put to neutral, where all circuits are open, so that no current is being generated by the generator, or it is put to the charging position, where current generated by the generator passes to the storage battery to charge it. When it is desired to start the car, the engine being running, the controller-switch handle is put into the first-speed position. The car being at rest, the armatures are at rest, but as the generator field is revolved by the engine, current is generated and sent to the motor field and through the motor armature back to the generator. It will be understood that the generator field in rotating tends to revolve the generator ar-

mature, and that the current generated due to the difference in speed between the generator field and armature shaft tends to revolve the motor armature; in consequence, the armature shaft is revolved and the car begins to move. The generator now gives its maximum current output and the greatest torque is exerted on the motor armatures; this controller-switch position corresponds to the low-speed position of the gear transmission, in which the greatest pulling power is obtained. Acceleration of the car or slowing down is now accomplished by throttle and spark control of the engine. To obtain a higher car speed, the controller switch lever is moved step by step to the high-gear position; most driving of the car is done with the switch lever in this position. When the controller switch is in its last, or high-gear, position, the generator is short-circuited in respect to the motor, under which condition the generator field exerts the greatest torque on the generator armature; the motor at the same time has been transformed into a differentially compounded generator and is connected in parallel to the storage battery, charging the same while the car is running.

Reverse is usually obtained mechanically by means of a small planetary transmission.

UNIVERSAL JOINTS

Hooke's Joint.—When two shafts are not exactly in line, these shafts may be connected by means of a *Hooke's joint*,

more commonly known as a *universal joint*, such as is shown in Fig. 8. Each of the four projections of the spider *a* has a pivot on which one of the fork ends of *b* or *c*

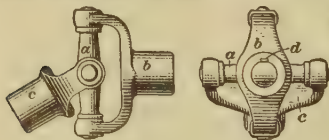


FIG. 8

is fitted. One of the shafts is fastened into the hub of *b* and the other into the hub of *c*.

There are many modifications of the form of universal joint here shown. If only one joint is used, the driven shaft will not

have a uniform motion. By placing a second coupling similar to the one shown and so placed that the forks that are attached to the intermediate shaft are parallel, the second joint will neutralize the tendency of the first joint to give the driven shaft a variable velocity.

Oldham's Coupling.—Shafts that are but slightly out of center or out of line may be connected by an *Oldham's coupling*, shown in Fig. 9.



FIG. 9

Each of the shafts *a* and *b* that are to be connected is provided, at the end next to the other shaft, with a flange in which a keyway is cut. A coupling block *c* provided with keys that fit into these keyways goes between these flanges. The keys on the block *c* are placed at right angles to each other so that the block needs no fastening.

DIFFERENTIAL GEARS

The purpose of a *differential gear*, or *differential* for short, is to permit the outer wheel of a pair of driving wheels to turn faster than the inner wheel when turning the car to either side.

Differential gears are divided into *bevel-gear differentials*, *spur-gear differentials*, and *gearless differentials*, of which the bevel-gear differential is now almost universally used.

The bevel-gear differential used on the Ford model T car is shown in Fig. 10, where part of the rear axle housing has been cut away so as to show the gears. The differential consists, in part, of the inner housing, or casing, *k*, to which is fastened the bevel driving gear *j*. Three small bevel pinions *l*, which are fitted to the inner housing *k* and are free to turn on their own axes, mesh with the gears *d* and *e*, which are keyed to the halves of the axle shaft. When the automobile is being propelled by the engine, the pinion *i* on the propeller shaft turns the inner housing *k* by means of the bevel driving gear *j*. The housing *k* carries the small pinions *l* bodily around with it, and these pinions, in turn, rotate the gears *d* and *e* and thus cause the axle shaft and the rear wheels to turn. When the automobile is traveling straight ahead, the gears *d* and *e* rotate at the same

speed because the road wheels rotate at the same speed; hence, the pinions *l* do not turn on their own axes, but remain stationary with respect to the housing *k*, simply forming a connection between the housing and the gears *d* and *e*. However, when the automobile turns a corner, or goes around a curve, the rotation of one rear wheel is resisted more than that of the other, or, in other words, the inner rear wheel is held back and does not travel so fast as the outer one, so that the gears *d* and *e* must be allowed to turn at different speeds in order that one of the road wheels will not skid. When this condition exists, the pinions *l*, besides being carried around bodily by the

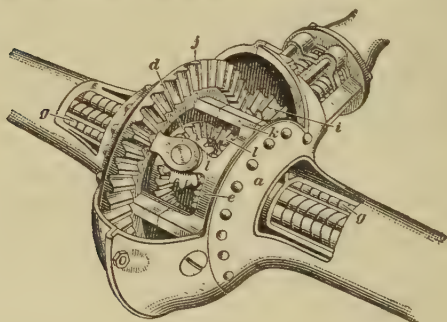


FIG. 10

housing *k*, turn on their own axes, and thus permit one of the gears *d* and *e* to rotate more slowly than the other and allow the road wheels to travel at different rates of speed and at the same time receive power from the engine.

In Fig. 11 is shown a spur-gear differential, the ends of the two shafts of which carry the gears *c* and *d*. The flange *e* is a part of the gear-case that carries a series of small gears *f* and *g*, arranged in four sets of two gears each. The two gears of each pair mesh together, and one is in mesh with the gear *c* while the other meshes with the gear *d*. By this arrangement, both gears *c* and *d* are drawn in one direction, and yet they may

turn with respect to each other when the resistance to the turning of one is greater than that of the other. When the resistance to the movement of gears *c* and *d* is the same, the four pairs of small gears *f* and *g* do not turn on their axles but simply carry the gears *c* and *d* around together.

There are several gearless differentials on the market; the *Bailey gearless differential* is shown in perspective in Fig. 12 (*a*), completely assembled but with part of the differential case broken away, and in (*b*) it is shown in cross-section; in (*c*) one of the ratchet plates is shown, and in (*d*) a ratchet plate inside one of the driving sectors, of which there is one over each ratchet. The ratchets *a*, *b* drive the two halves of the axle shaft *c*. There are two walking beams, or pawls, *d* free to rock on the center ring *e* that form the interlocking mechanism between the ratchet plates *a*, *b* and the driving sectors *f*, which are rigidly attached to the differential case *g*. When going straight ahead with the car, the pawls *d* are in the positions shown in (*b*) and (*d*); the lower pawl locks the left ratchet *a* to the right driving sector *f*, and the upper pawl locks the right ratchet *b* to the left driving sector. Both rear wheels are thus positively driven when going straight ahead. Now assume the car is turning to the right; the left rear wheel then begins to turn faster than the right and therefore the left ratchet *a* turns faster than the differential case *g*. The left end of both pawls *d* is thereby pushed out of each notch of the left ratchet *a* around their right ends as fulcrums, and the ratchet therefore can turn independently of the differential case. As soon as the car moves straight ahead again, the helical springs *h* push the pawls *d* back again into the positions shown in (*b*) and the whole differential is locked once more.

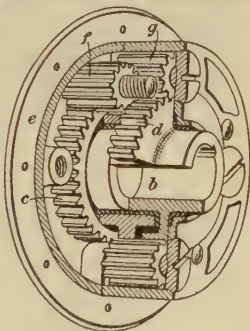


FIG. 11

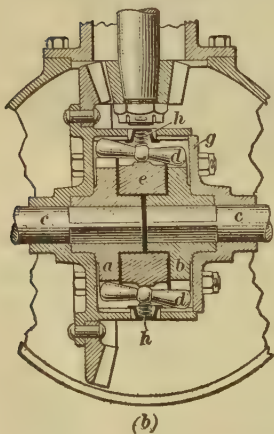
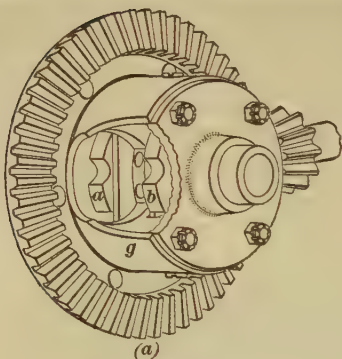


FIG. 12

STEERING MECHANISM

Ackerman Steering System.—In order that the automobile may pass around a corner without making one or the other of the front wheels slip sidewise, the knuckle joints about which the wheels swing should be so arranged that the extended axes of the wheels intersect on the center line of the rear wheels. An arrangement that substantially satisfies this condition is shown in Fig. 13. The steering knuckles *a* and *b* are connected by the distance rod *c* and they are pivoted at *d* and *e*, respectively. When the front wheel on the left is turned into the position shown by the dotted lines, the wheel on the right will be in the position shown by the dotted lines on that side. With the wheels in this position the axes of the front wheels intersect each other and the center line of the rear wheels in the point *g*, which satisfies the condition stated above. The wheels are made to swing in this way by arranging the steering arms of the knuckles *a* and *b* so that the line drawn through the pivot *d* and the joint between *a* and *c* will intersect a similar line from the knuckle *b* in the point *f* where the center line of the car crosses the center line of the rear axle. This arrangement is known as the *Ackerman steering system*, and, while not mathematically exact, gives a fairly close approximation.

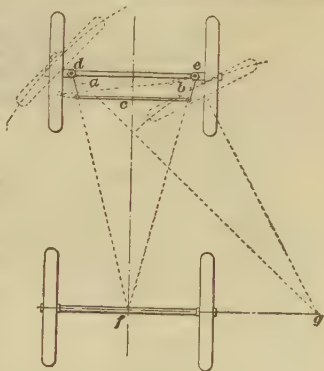


FIG. 13

arms of the knuckles *a* and *b* so that the line drawn through the pivot *d* and the joint between *a* and *c* will intersect a similar line from the knuckle *b* in the point *f* where the center line of the car crosses the center line of the rear axle. This arrangement is known as the *Ackerman steering system*, and, while not mathematically exact, gives a fairly close approximation.

Steering Gears.—The tiller steering gear is one of the simplest forms in use. The steering lever is fastened to the top of the steering column, which is in front of or to one side of the operator, and the lower end of the steering column is attached, by suitable connections, to one of the steering

knuckles. When one of the front wheels strikes an obstruction not met by the other wheel, this form of steering gear will permit the car to turn to one side unless the tendency to turn is resisted by the operator. The tiller steering gear is therefore said to be reversible and is only suitable for light cars, and at present is not used except for electric cars.

In the more common form of steering gear, a wheel is fastened to the top end of the steering post, which has a worm attached to its lower end. The turning of the steering wheel is then transmitted to a worm-wheel and from it to the front wheels. Owing to the fact that the worm-wheel cannot easily make the worm rotate, this steering gear is not easily reversible and the car will run in the direction for which the steering gear may be set until the operator turns the steering wheel. Instead of a worm and worm-wheel an equivalent mechanism is often used.

BRAKE MECHANISM

The brakes used in automobile practice consist of a cylindrical member, or *brake drum*, attached to some rotating part, and a contracting or expanding member, or *brake band*, supported by some fixed part of the car. The brake band is applied by levers operated from a pedal or hand-brake lever. If the band is of the contracting type and is applied to the outside of the drum, the brakes are called *contracting brakes*; if it is an expanding band and is applied to the inside of the drum, they are called *expanding brakes*. It is the usual practice to fit two entirely separate sets of brakes to automobiles. The one brake system is used in ordinary service, and is therefore called the *service brake*. The second brake system is intended for emergency use, and hence the term *emergency brake* is applied to it.

It is the common practice to apply the service brake and the emergency brake to a drum fastened to each rear wheel. In many cars, however, the service brake is applied to the brake drum on the rear wheel, but the emergency brake acts on a drum carried by the transmission shaft. The braking effort in such cases acts through the outer differential gears instead of through the wheel hubs. Either the service brake

may be of the contracting type and the emergency brake of the expanding type, or the opposite may be true. There is no fixed rule governing the type of either set of brakes. In a few cars, however, both sets of brakes are of the expanding type and are located side by side within a single brake drum.

The most common form of hub brake consists of a contracting brake, operated by means of a bell-crank, and an expanding brake, operated by means of a cam. An example of this form is found in some designs of the Timken-Detroit rear

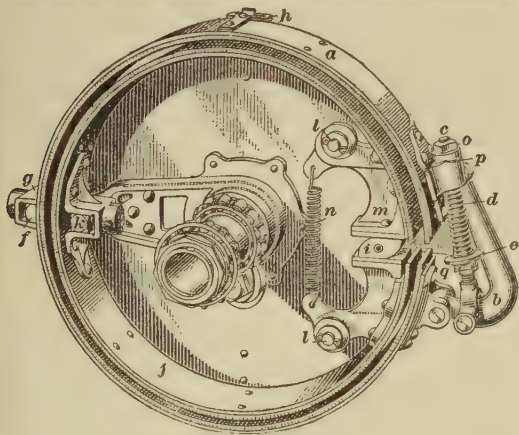


FIG. 14

axes, and is shown in Fig. 14. In order to show the details of the operating mechanism the brake drum is omitted from the illustration.

The contracting band *a* is lined with wire-woven asbestos fabric. It is attached at one end to the short arm of a bell crank *b*, and at the other end it connects through a short link *c* to the fulcrum of the bell-crank. The long arm of the bell-crank may be connected by rods and levers to either a pedal or

a hand lever, and the brake is then applied by exerting a pull in the proper direction on this arm. When the brake pedal or lever is released, the elasticity of the steel band *a* draws it away from the drum. In addition to this, a releasing spring *d* is provided. This spring seats on a stop *e* that is stationary, so that when the brake is applied, the spring is compressed. When the brake is released, the spring expands and helps to expand the band *a*. On the side of the brake opposite the operating mechanism, there is a support *f* that helps to carry the band by means of a bracket *g*. Between the support and the outer part of the bracket there are two springs that tend to keep the brakes from rubbing on the drums when not in use. The action of these springs can be limited by means of an adjusting screw. Two supports *h*, one located on top and the other on the bottom of the band *a*, preserve the brakes in their correct alinement.

In the cam-operated expanding brake the double cam *i* acts on bearing surfaces carried on the ends of the asbestos-lined band *j*. The band *j* is supported at *k* in the same manner that the band *a* is supported at *f*. Two stops *l*, which are pins secured to the axle housing and passing through slotted holes in the brackets *m*, hold the expanding band in side-wise alinement. The spring *n* is the releasing spring and holds the ends of the band in contact with the cam *i*. The supports *f* and *k* are carried on an extension of the axle housing.

Adjustment of the contracting brake is made by means of the nut *o* on the end of the link *c*. This nut is provided with a notch *p* that fits over a corresponding projection on the supporting bracket; hence, the least adjustment that can be made is one-half of a turn of the nut. The adjusting nuts at *q* are used for centering the band on the brake drum, the nut *o* taking care of the actual adjustment.

The expanding brake is adjusted by lengthening or shortening the brake rod by means of a suitable turnbuckle.

In order that the braking effect may be as nearly as possible the same on each of the wheels, it is necessary to use some form of *equalizer*. Any system of levers that will insure an equal pull on the two brakes will serve this purpose.

Overhauling Brakes.—If the rear-wheel brake drums are fitted with expanding and contracting brakes, and the latter are operated by the service-brake pedal, the drums will quickly wear on their outside braking surface into concentric grooves and ridges, on account of the road dust and dirt that continually find their way between the drums and the brake bands. There is usually little wear on the inside of the brake drum, even if the expanding brakes are used as service brakes, because as a general rule there is little chance for excessive dust and dirt to get inside the brake drum. The only time excessive wear will be found inside the drums is when the metallic brake shoes bear directly against the drum when the brakes are applied, as in the case of the Ford emergency brake.

With the rear wheels removed from the axle, the brake drums are cleaned, inspected, and the amount of wear noted. If the drums are rather thin they should be inspected for cracks due to applying the internal brakes, irrespective of whether they are of cast material or of pressed steel, the cast material being more liable to fracture than the pressed steel, however. The brake drums of rear wheels are rarely thick enough to permit turning them smooth when excessively grooved; the only practical remedy is to apply new drums. Service brakes on a brake drum carried by the transmission shaft are not so exposed to dirt as rear-wheel brakes and consequently will last much longer.

The brake shoes of internal expanding brakes and the brake bands of external contracting brakes are lined with a wire-woven asbestos fabric lining, which is made in several thicknesses, from $\frac{1}{8}$ to $\frac{1}{4}$ inch, and in width varying by quarter inches. This brake lining is sold under various trade names, as, for instance, Motobestos, Thermoid, Raybestos, Brakebestos, J. M. Non-Burn, Multibestos, etc., by automobile supply houses.

The low-speed brake band, reverse-brake band, and service-brake band on the transmission of the model T Ford engine should not be lined with a wire-woven asbestos brake lining, because the particles of metal worn off such a brake lining are very liable to short-circuit the magneto used in the engine of that car. Special asbestos brake linings are made for use on the transmission brake bands of the model T Ford; these

asbestos linings do not contain any metal and are superior to leather or camel's-hair belting, and can be obtained from most automobile supply houses.

The brake lining is usually attached to brake shoes or brake bands by means of copper rivets known as *belt rivets*. The first step is to cut off the old rivet heads with a sharp cold chisel or a coarse file on the side of the brake opposite the lining. The rivets can then be punched out. If the holes for the rivets have been countersunk the rivets either have to be drilled out or the large head embedded in the lining has to be cut off with a chisel and the rivets punched out from the side of the brake that receives the lining. In the case of contracting band brakes the brake band is made of spring steel and is quite thin; considerable care must hence be exercised in cutting out the rivets not to bend the brake band out of shape.

When the old lining is removed, a hole is drilled or punched with a belt punch at one end of the new lining to register with the first rivet hole of one end of the brake shoe or brake band; the lining is then countersunk with a carpenter's countersink so that the large head of a belt rivet will sink below the surface of the lining. The lining can now be riveted on at the first rivet hole. With the lining bent to fit the brake shoe or brake band, the second rivet hole can now be marked off or drilled in place, the hole then countersunk, and the second rivet driven. This process is repeated until all rivets have been driven. If the brake lining is not properly countersunk the rivet head will soon touch the brake drum and the brakes will screech whenever they are applied.

The wire-woven asbestos brake lining can be cut with tinsmith's shears, or *snips*; thick lining is easiest cut with a hack saw. Copper belt rivets of any size can be obtained from any automobile supply house or hardware store. Be sure to obtain rivets with reasonably large heads so that they will not pull through the brake lining. Never use iron or steel rivets for brake linings, as projecting heads will wear grooves in the drums.

FRAME REPAIRS

The repair of a cracked side rail of the frame, which crack may extend only part way or entirely through the rail, depends on circumstances. The best practice is to have the frame welded at an oxyacetylene welding plant. The rail may be welded in place at a comparatively small cost, reinforcing it at the weld. When welding for any reason is not practicable, repairs can often be executed at a machine shop, boiler shop, or even at a blacksmith shop, by fastening a steel plate of the same depth as the rail and perhaps one and one-half times its thickness, to the inside or outside of the broken rail. The plate should be at least six times the depth of the rail in length, and can be longer. If the plate is fastened by rivets, these should be driven hot; if the plate is bolted on, the bolts and nuts should be finished ones made to the Society of Automobile Engineers (S. A. E., also given as A. L. A. M.) standard, and be a good fit in their holes. Ordinary rough machine bolts or United States standard capscrews should not be used in frame repairs, as they are much weaker than the same size bolts made to the A. L. A. M. standard, and are made of poorer material.

When rivets attaching spring horns, spring seats, brackets, cross-members of the frame, etc. are found loose, the loose rivets should be cut out and new rivets driven hot, as a loose rivet tightened by riveting it more will come loose again as soon as a stress comes on it. Very often it will be found impossible to drive a new rivet in place of a loose one, it not being possible to reach the rivet with a suitable hammer; in such cases the rivet hole should be reamed out and a bolt made of good material driven into the hole and secured with a nut having a fine thread, riveting over the end of the bolt.

When spring horns or spring seats are found cracked, it is generally less expensive to fit new pieces than to weld the broken piece in place with the oxyacetylene torch. There are exceptions, however, and hence both methods of repair should be investigated in each case. It may not be possible to attach a new spring seat, spring horn, or similar part to a frame by riveting; bolts that are a driving fit in their holes should then be used and the nuts should be properly secured.

EXAMINING A CLUTCH

The examination of a multiple-disk clutch is ordinarily a matter of observing how much the disks are worn; but it is also desirable to open up a clutch that has been used for some time in order to remove foreign matter, including metal particles worn from the disks, that may have collected inside the casing. On account of the many designs of disk clutches, it is not possible to give any detailed instructions about taking them apart. It should be noted that the tendency of the closing spring to expand or otherwise gain its unstressed form may cause severe injury to the person that is removing the part that holds it in place, unless due provision is made for the sudden snapping free of the spring.

The disks of a metal-to-metal multiple-disk clutch generally wear most rapidly at the edge farthest from the part that supports and drives them. They can therefore be used until this edge becomes very thin—almost to a knife edge in some cases. If all the disks were originally of the same thickness, the allowable wear for each disk would be half its original thickness. When this much has been worn away uniformly over the bearing surface, the adjacent disks that form one set, as the inner or outer set of disks, will come into contact with each other at their unworn surfaces, thus preventing pressure against the intermediate disks of the other set.

The disks of dry-plate clutches are faced with friction fabric, which is usually wire-woven asbestos fabric; the thickness of this facing should be examined. If this facing has worn to less than half its original thickness, it is advisable to remove it from all the faced disks by cutting out the copper rivets attaching the facing to the disks, and to fit new fabric. This clutch-disk facing can be bought, cut to the right shape, from the factory where the car or engine was made, or it can be cut with tinsmith's snips from brake lining of the proper kind, width, and thickness, using one of the worn-out segments of friction fabric as a pattern. In cutting out the copper rivets, and also in riveting new facing to the disks, care should be exercised not to bend or otherwise distort the disks. Care should be taken to have the rivet heads well below the surface of the friction fabric.

The feather keys, splines, or grooves that engage the disks and drive them, or by means of which the disks drive a part to which power is transmitted, sometimes wear in notches where the edges of the notches or projections of the disks press against them. This kind of wear prevents quick opening of a clutch when it is disengaged, and causes drag. The worn notches should therefore be removed from the feather keys, splines, or grooves with which the disks engage.

With leather-faced cone clutches, it is difficult to tell how they operate without trial; yet, if the leather facing is so thin that it allows the cone to enter so far that the inner cone strikes against the back of the outer cone, or if the leather is very much glazed and shows evidence of charring from overheating, a new leather should be put on. The condition of the leather cannot generally be determined without at least partly separating the friction members of the clutch. In doing this, the same precautions must be observed in regard to the closure spring as with disk clutches.

The yoke and bearing used to release cone and disk clutches should be examined for wear. When constructed in such a manner that they cannot be kept well lubricated all the time, the wear on such thrust bearings is sometimes very rapid. Plain thrust bearings especially are apt to cut out in a very short time. When a ball bearing is used to take the thrust of releasing a clutch, the condition of the balls and races should be determined, the examination being for the same indications of wear as in any other ball bearing.

Relining Cone Clutch.—A friction leather for a cone clutch is curved as shown in Fig. 1 (*a*), because the leather is fitted to a cone instead of to a cylinder. The radius of the circle of which the outside edge *b d* of the leather forms a part when flattened out is equal to the slant height of the cone, as shown by the distance *a c* in (*b*). The point *c* is found by extending the sides *a a'* and *b b'* of the cone until they meet at the apex *c* of the cone. The distance *a c* and the angle of the cone cannot be determined when the parts of the clutch, of which the cone forms a part, are together, or in place on the car. The usual method of procedure, therefore, is to take off the old leather and use it as a pattern for cutting a new leather.

The length of a rectangular piece of leather required for a new cone leather can be taken as three times the large diameter of the cone, including the leather on it. The width of the leather strip depends on the angle of the cone and also on the width of the cone. In any ordinary design a rectangular piece four times as wide as the width of the leather strip that goes on the cone will be sufficient. If the leather procured for making the cone covering is too narrow, the strip can be cut out in two pieces, each long enough to go half way round the cone. These pieces will answer as well as a single piece, although they may be a little more difficult to put in place. Most metal cones have four or more holes drilled close together near the point where the ends of the leather meet.

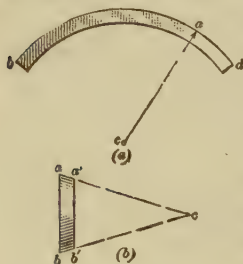


FIG. 1

Leather clutch lining cut to the exact shape can usually be obtained from the maker of the car or engine, if the concern is still in existence.

A convenient method of putting on the new leather is first to fasten one end by a rivet placed through one of the holes near the point where the ends are to come and then to wrap the leather around the cone, holding it as nearly as possible in position. The leather is then cut so that the ends come

within $\frac{3}{8}$ to $\frac{1}{2}$ inch of each other. After drawing the two ends together, they are fastened by the rivets. The leather is then pressed at some other point on the cone as far as it will go, and riveted in place. It is generally best to make the second fastening diametrically opposite the ends of the leather. The next fastening can then be placed midway between the places that are already fastened, making four fastenings each a quarter of the way around the cone from the other, and so on until all the rivets are in place. It is better to press the leather on the cone before marking the holes, unless the exact location of these holes can be obtained from another piece.

TEMPORARY SPRING REPAIRS

If the spring breaks completely in two as shown in Fig. 1 (a), the spring repairer *a* can be used temporarily. When of sufficient strength and securely bolted in place by the clips *b*, it will carry the car almost as well as an uninjured spring.

If the leaves of the spring are broken off at some distance from the axle, as shown in (b), the fracture being at *a*, the spring can be repaired by bolting a curved bar of metal *b* to the spring, as shown. The curvature of the re-

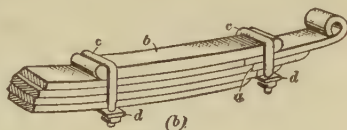
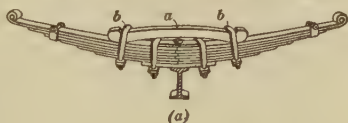


FIG. 1

pair bar should be about the same as that of the spring when the usual load is resting on it. The clips *c* must be firmly clamped in place by the spring-clip yokes *d*.

Either bar can be made by any blacksmith, using a piece of bar steel about $\frac{1}{2}$ inch thick and the same width as the spring. The bar should have its ends slightly turned up so that the spring clips cannot slip off.

Breakage of the spring at the middle is very often due to loose spring clips. With the spring clips loose, the leaves are not bound tightly together and therefore bend sharply at the middle on the rebound.

BEARINGS

CLASSIFICATION OF BEARINGS

Bearings may be divided into three classes, plain bearings, roller bearings, and ball bearings. Any one of these bearings may be made to take either radial or longitudinal pressure. Plain bearings are, however, seldom made to take longitudinal thrust in automobiles. A bearing that takes longitudinal thrust is called a *thrust bearing* and those taking radial press-

sure are called *radial bearings*. Both roller and ball bearings are frequently made for thrust as well as radial pressure.

PLAIN BEARINGS

The simplest form of *plain bearing* is simply a hole in which the shaft turns. Better forms, however, use some form of lining for the hole in which the shaft turns. When the shaft is made of steel, as is usually the case, it is customary to make the other part of the bearing of Babbitt, white brass, or bearing bronze. Any lubricant, such as oil, in a bearing of this kind forms a film over the rubbing surfaces, thus separating them slightly and reducing the friction. The capacity of a bearing of this kind depends largely on the lubricant used. When the pressure on the bearing becomes so great that the lubricant is squeezed out of the bearing and the rubbing surfaces are permitted to come into contact, the bearing will become heated and may be seriously damaged.

ROLLER BEARINGS

A tapered roller bearing, as implied by the name, employs tapered rollers, that is, rollers that are frustums of cones, running in contact with tapered inner and outer races. The bearing of this form most widely used in automobile work is the *Timken roller bearing*, which is shown in Fig. 1. In (a) is shown a section through the inner and outer race with a roller *a* between the conical (tapered) surfaces of the inner race *b* and the outer race *c*. The inner race is cylindrical on its inside, and the outer race on its outside. The inner race has two ribs with conical sides, the rib *d* entering a corresponding groove *e* in the small end of the roller *a*. The conical face of the rib *f* bears against the conical large end of the roller, as shown. The ribs *d* and *f*, in conjunction with a cage in which the rollers are set, hold the rollers in proper alinement with the races. The cage is shown separately in (b); it is pressed in one piece from sheet steel into the form shown. The inner race is shown in perspective in view (c), and assembled with the cage and rollers in (d). When thus assembled, the inner race, cage, and rollers cannot separate. The outer race is shown separately in (e), and the whole bearing assembled in (f).

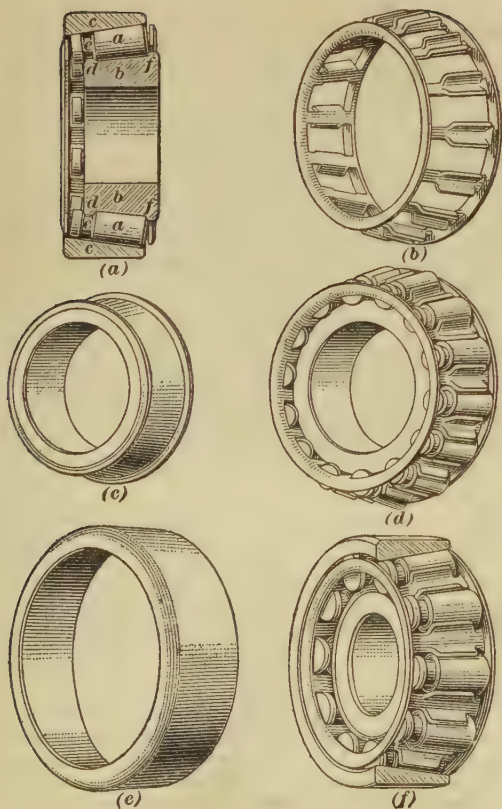


FIG. 1

The outer and inner races have their bearing surfaces formed as frustums of cones whose apexes coincide and lie on the center line of the journal; the center lines of the rollers lie on the surface of a cone whose apex coincides with that of the inner and outer races, and consequently the rollers have a true rolling motion. As in cylindrical roller bearings, the cage for the rollers prevents their sidewise displacement.

A tapered roller bearing carries radial and axial loads, and any radial looseness due to wear is readily taken up by forcing the inner race farther into the outer race. This form of bearing is always mounted so as to permit this operation to be easily done. The races and rollers are made of hardened steel and are very accurately ground after hardening. Tapered roller bearings are largely used in the construction of rear axles, and

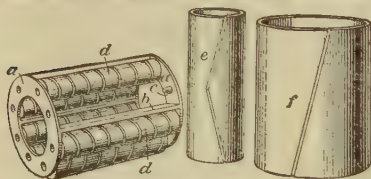


FIG. 2

for the front wheels.

The *Hyatt roller bearing*, one form of which is shown in Fig. 2, has rollers that are made by coiling flat stock helically into a

cylinder. The rollers are held in a cage formed of rings *a*. These rings are held together by connecting pieces *b* that have projections *c* for retaining the rollers *d*. This form of roller bearing is often used with casings *e* and *f* formed from sheet steel, the one being placed on the journal and the other outside the rollers; in other cases the rollers are used without a casing over the journal. In *Hyatt high-duty bearings* the casings are solid, and they as well as the rollers are hardened and ground.

There are on the market several makes of straight roller bearings with solid cylindrical rollers; some of these bearings are arranged to take not only a radial but also an axial load; others are suitable only for a radial load and a special thrust bearing must be provided for axial loads.

BALL BEARINGS

In accordance with the character of the loads ball bearings are intended to carry, they are divided into *radial ball bearings*, *ball thrust bearings*, and *radial-and-thrust ball bearings*.

Radial ball bearings are divided into two general types: the *full ball bearing* and the *silent ball bearing*. Each type may have a single row of balls, when it is called a *single-row ball bearing*, or it may have several rows of balls, when it is called a *multiple-row ball bearing*. In present automobile work, a radial ball bearing with more than two rows of balls is hardly ever found. Radial ball bearings are often spoken of as *annular ball bearings*, there being an annular space between the inner and the outer race, which space contains the balls.

A full-type annular ball bearing with a single row of balls is shown in Fig. 3 (a), in which illustration part of the outer race *a* is cut away in order to show the assembly. The outer race *a* and the inner race *b* are grooved to a larger radius than that of the

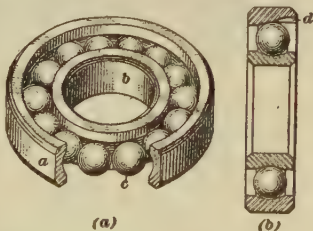


FIG. 3

balls *c* in order that the balls may be in contact with each race at a single point in the same plane as the centers of the balls. The balls are introduced between the races through a slot in the outer race, which slot cannot be seen in view (a), but is indicated at *d* in the cross-section shown in (b).

Annular ball bearings of the silent type have their balls set in cages, so that they cannot come in contact with each other. They derive their name from the absence of the clicking sound, caused by the balls striking against each other that is found in ball bearings of the full type. Silent-type annular bearings are made by many different firms, the various makes differing from each other chiefly in the form of cage that is employed.

Whether or not an annular silent-type ball bearing that forms a unit when assembled must have filler slots cut in the races is determined largely by the number of balls the manufacturer has decided to use between the races. When a large number of balls are used, the bearing must have filler slots in its races; sometimes the outer race has a filler slot, sometimes the inner race has such a slot, and sometimes both races have these slots. It is possible to design an annular ball bearing in such a manner that it can be entirely filled with balls or be made of the silent type, just as is desired, without having filler slots in either race; a full ball bearing of this type, however, will not be a unit when assembled.

Although annular ball bearings are designed primarily to carry a radial load, they can safely carry an axial load equal to about one-tenth the safe radial load. When the axial load becomes greater than is safe, this load should be taken by a separate thrust bearing, which may be combined into a single unit with the radial bearing, but more frequently is entirely separate.

The manufacture of single-row annular ball bearings is standardized to a large degree, so that bearings made by different manufacturers, but having the same trade number, will interchange perfectly. The single-row annular bearings in most common use are made in five series, in both the full and silent types. These series are as follows:

1. *Medium and Heavy Series, Narrow Type.*—Bearings of this series are designated by numbers that identify them, and are below 100.
2. *Light Series, Narrow Type.*—The identification numbers begin with 100 and are below 200.
3. *Light Series, Wide Type.*—The identification numbers begin with 200 and are below 300.
4. *Medium Series, Wide Type.*—The identification numbers begin with 300 and are below 400.
5. *Heavy Series, Wide Type.*—The identification numbers begin with 400 and are below 500.

The identification number is usually stamped on one of the races, and sometimes on both, and even on the ball cage. When this number is known, the series is also known; thus, if

SINGLE-ROW ANNULAR BALL BEARINGS, MEDIUM AND HEAVY SERIES, NARROW TYPE

No. of Bearing	Inside Diameter		Outside Diameter		Width	
	Inches	Milli-meters	Inches	Milli-meters	Inches	Milli-meters
1	.4724	12	1.4567	37	.3543	9
2	.5905	15	1.5748	40	.3543	9
3	.7874	20	2.0472	52	.3937	10
4	.9843	25	2.4409	62	.4724	12
5	1.1811	30	2.8346	72	.5118	13
6	1.3780	35	3.1496	80	.5512	14
7	1.5748	40	3.5433	90	.6299	16
8	1.7717	45	3.9370	100	.6693	17
9	1.9685	50	4.3307	110	.7480	19
10	2.1653	55	4.6063	117	.7480	19
11	2.3622	60	5.0000	127	.7874	20
12	2.5591	65	5.3937	137	.8661	22
13	2.7559	70	5.7874	147	.9449	24
14	2.9528	75	6.1811	159	.9843	25
15	3.1496	80	6.6141	168	1.0630	27
52	.7874	20	2.5591	65	.5512	14
53	.8661	22	2.8346	72	.6299	16
54	.9843	25	3.1496	80	.6693	17
55	1.0630	27	3.4645	88	.7480	19
56	1.1811	30	3.7402	95	.7874	20
57	1.3780	35	4.0551	103	.8661	22

an annular ball bearing is stamped 308, it belongs to the medium series, wide type.

The identification numbers and sizes of the most common single-row annular ball bearings are given in the accompanying tables, the sizes being given in both millimeters and inches.

Although the practice of designating annular single-row ball bearings by the numbers here given is commonly followed, there are exceptions. Thus, the New Departure bearings of this type have the figure 1 prefixed to the trade numbers given in the tables. For instance, the New Departure bearing having the number 1404 has an inside diameter of 20 mm., an

SINGLE-ROW ANNULAR BALL BEARINGS, LIGHT SERIES, NARROW TYPE

No. of Bear- ing	Inside Diameter		Outside Diameter		Width	
	Inches	Milli- meters	Inches	Milli- meters	Inches	Milli- meters
102	.3937	10	1.2598	32	.3543	9
103	.5905	15	1.4567	37	.3543	9
104	.7874	20	1.6535	42	.3543	9
105	.9843	25	2.0472	52	.3543	9
106	1.1811	30	2.4409	62	.3937	10
107	1.3780	35	2.7559	70	.3937	10
108	1.5748	40	3.1496	80	.4331	11
109	1.7717	45	3.3465	85	.4331	11
110	1.9685	50	3.5433	90	.4331	11
111	2.1653	55	3.9370	100	.4724	12
112	2.3622	60	4.1339	105	.4724	12
113	2.5591	65	4.5275	115	.5512	14
114	2.7559	70	4.7245	120	.5512	14
115	2.9528	75	5.1182	130	.6299	16
116	3.1496	80	5.3149	135	.6299	16
117	3.3465	85	5.7086	145	.7087	18
118	3.5433	90	5.9056	150	.7087	18
119	3.7402	95	6.2992	160	.7874	20
120	3.9370	100	6.4960	165	.7874	20
121	4.1339	105	7.0867	180	.8661	22
122	4.3307	110	7.2834	185	.8661	22

outside diameter of 72 mm., and a width of 19 mm., which are the same dimensions as those of bearing No. 404. No confusion arises in practice from these differences of numbering when a bearing is to be replaced by one of the same number and of the same make; when it is to be replaced by one of a different make, either the maker or his catalog is consulted for the trade order number.

It must not be inferred that only the bearings given in the tables are manufactured; smaller or larger bearings can be obtained in the five series, either on regular or special order, and special sizes to suit special conditions are also manufactured.

SINGLE-ROW ANNULAR BALL BEARINGS, LIGHT SERIES, WIDE TYPE

No. of Bear- ing	Inside Diameter		Outside Diameter		Width	
	Inches	Milli- meters	Inches	Milli- meters	Inches	Milli- meters
204	.7874	20	1.8504	47	.5512	14
205	.9843	25	2.0472	52	.5905	15
206	1.1811	30	2.4409	62	.6299	16
207	1.3780	35	2.8346	72	.6693	17
208	1.5748	40	3.1496	80	.7087	18
209	1.7717	45	3.3465	85	.7480	19
210	1.9685	50	3.5433	90	.7874	20
211	2.1653	55	3.9370	100	.8268	21
212	2.3622	60	4.3307	110	.8661	22
213	2.5591	65	4.7244	120	.9055	23
214	2.7559	70	4.9213	125	.9449	24
215	2.9528	75	5.1181	130	.9843	25
216	3.1496	80	5.5118	140	1.0236	26
217	3.3465	85	5.9055	150	1.1024	28
218	3.5433	90	6.2992	160	1.1811	30
219	3.7402	95	6.6929	170	1.2598	32
220	3.9370	100	7.0866	180	1.3386	34
221	4.1339	105	7.4803	190	1.4173	36
222	4.3307	110	7.8740	200	1.4961	38

Neither does each manufacturer necessarily make all five series of annular single-row ball bearings.

In a very few instances, automobile manufacturers have made their own annular bearings to their own standards; such bearings, for replacement purpose, must, as a general rule, be obtained from the proper automobile manufacturer.

All annular ball bearings are non-adjustable; they are properly assembled at the factory and are intended to be replaced with new ones when worn to an objectionable degree. In many cases, worn annular ball bearings can be repaired, however, at small cost, either at the factory where they were made or at establishments specializing on this class of repair work. The repair is effected by regrinding both races and

SINGLE-ROW ANNULAR BALL BEARINGS, MEDIUM SERIES, WIDE TYPE

No. of Bearing	Inside Diameter		Outside Diameter		Width	
	Inches	Milli-meters	Inches	Milli-meters	Inches	Milli-meters
300	.3937	10	1.3780	35	.4331	11
301	.4724	12	1.4567	37	.4724	12
302	.5906	15	1.6535	42	.5118	13
303	.6693	17	1.8504	47	.5512	14
304	.7874	20	2.0472	52	.5905	15
305	.9843	25	2.4409	62	.6693	17
306	1.1811	30	2.8346	72	.7480	19
307	1.3780	35	3.1496	80	.8268	21
308	1.5748	40	3.5433	90	.9055	23
309	1.7717	45	3.9370	100	.9843	25
310	1.9685	50	4.3307	110	1.0630	27
311	2.1653	55	4.7244	120	1.1417	29
312	2.3622	60	5.1181	130	1.2205	31
313	2.5591	65	5.5118	140	1.2992	33
314	2.7559	70	5.9055	150	1.3780	35
315	2.9528	75	6.2992	160	1.4567	37
316	3.1496	80	6.6929	170	1.5354	39
317	3.3465	85	7.0867	180	1.6142	41
318	3.5433	90	7.4803	190	1.6929	43
319	3.7402	95	7.8741	200	1.7717	45
320	3.9370	100	8.4646	215	1.8504	47
321	4.1339	105	8.8583	225	1.9291	49
322	4.3307	110	9.4488	240	1.9685	50

substituting larger balls; owing to the special machinery and the high degree of workmanship required, this work cannot be done in garages or ordinary machine shops, but must be done by specialists.

The great success that has been obtained with annular bearings is in a large degree to be attributed to their non-adjustability, which feature prevents their overloading by a wrong adjustment.

In automobile work are used two forms of ball thrust bearings that may be classified as *plain* and *self-aligning thrust*

SINGLE-ROW ANNULAR BALL BEARINGS, HEAVY SERIES, WIDE TYPE

No. of Bearing	Inside Diameter		Outside Diameter		Width	
	Inches	Milli-meters	Inches	Milli-meters	Inches	Milli-meters
403	.6693	17	2.4409	62	.6693	17
404	.7874	20	2.8346	72	.7480	19
405	.9843	25	3.1496	80	.8268	21
406	1.1811	30	3.5433	90	.9055	23
407	1.3780	35	3.9370	100	.9843	25
408	1.5748	40	4.3307	110	1.0630	27
409	1.7717	45	4.7245	120	1.1417	29
410	1.9685	50	5.1181	130	1.2205	31
411	2.1653	55	5.5119	140	1.2992	33
412	2.3622	60	5.9055	150	1.3780	35
413	2.5591	65	6.2992	160	1.4567	37
414	2.7559	70	7.0867	180	1.6535	42
416	3.1496	80	7.8740	200	1.8898	48
418	3.5433	90	8.8583	225	2.1260	54
420	3.9370	100	10.4331	265	2.3622	60

bearings. Either class may belong to the silent or the full type of bearing.

A plain ball thrust bearing of the silent type is shown completely disassembled in Fig. 4 (a). It consists of two grooved

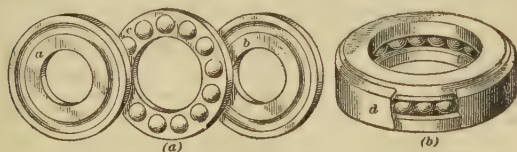


FIG. 4

hardened-steel races *a* and *b*, between which is placed the ball cage *c* containing the balls. In the full type, no cage is

employed. Both the full and silent types are sometimes assembled with a retaining band *d* around them, as shown in view (b), so that the races and balls cannot come apart when the bearing is removed from its place. In the plain ball thrust bearing, careful machining of the seats for the two races is relied on to distribute the thrust load evenly over all the balls; it is evident, however, that the slightest springing of shaft or

housing will throw all the load on one or two balls.

Self-aligning ball thrust bearings are so constructed that they will automatically adjust themselves in such a manner that the thrust load at all times is carried by all the balls.

The earliest form of ball bearing suitable for combined radial and thrust loads was developed in the early days of the bicycle industry, and from the form of its races it is called the *cup-and-cone ball bearing*. Such a bearing is shown in cross-section in Fig. 5.

The *cup* *a* forming the outer race is so shaped that it comes in contact with each ball at two points, as at *b* and *c*; the *cone* *d* forms the inner race and is in contact with each ball at a point. There are thus three points of contact for each ball, whence the name *three-point ball bearing* is derived. A groove is turned in the outer race, into which is sprung a split retainer ring *e*, the purpose of which is to retain the balls in the cup when the cone is removed. This bearing can carry a thrust load in only one direction, which is indicated by the arrow *f*. The cone in this particular case is the stationary member of the bearing, and the cup the movable member; but in other cases the cup is the stationary member.

With the ordinary cup-and-cone ball bearing, it is customary to fill the space between the cup and the cone with as many balls as it will hold; that is, to make it a full-type bearing.

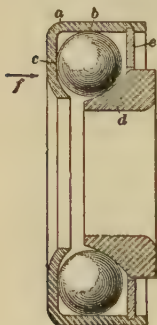


FIG. 5

LUBRICATION

LUBRICANTS

Lubrication consists in introducing some substance, either liquid or solid, between two rubbing surfaces, to reduce the friction and the wear that otherwise would occur. No matter how smooth a metallic surface may appear to the sight or to the touch, it is in reality covered with very minute projections or ridges and hollows. Hence, when two clean metallic surfaces are placed together and one is made to slide or roll upon the other, these little ridges engage one another with the result that some of the projections are torn loose from each piece.

When a lubricating substance, or *lubricant*, is put between the two surfaces, it fills the little hollows and forms a thin film, or layer, that prevents the metals from actually touching each other except at the points of the highest ridges. As a result there is less wear, as a smaller number of ridges are torn loose, and this means less friction also.

The lubricants used in automobile practice are oils, greases, graphite, mica, French chalk, etc. Oil is a *liquid* lubricant; grease is a *semiliquid* lubricating substance; graphite, mica, French chalk, etc. are *solid* lubricants.

Grade of Oil.—For engines used in automobile and aeroplane service, the grade of cylinder oil known as *medium* is appropriate for summer use. In weather cold enough to cause this oil to stiffen, the next lighter grade, or *light*, may be employed. In cold weather, if the *light* oil does not feed freely, it is best to use a special oil suitable for use at low temperatures. It is best in every case to purchase oil that is known to be reliable. Besides, most manufacturers of automobiles recommend certain oils for use in their engines. These oils may always be used with confidence in any engine of about the same character as that for which they are put up.

Greases.—The greases used in automobile work are made in different consistencies to suit different climatic conditions and service. A distinction is usually made between *cup greases* which are intended to be used in grease cups and *transmission* greases.

In places such as spring and shackle bolts and other places

exposed to little heat, grease cups have been largely replaced by oil cups. These parts must be oiled periodically to prevent friction and undue wear. Many manufacturers recommend the use of a heavy, steam-engine cylinder oil, such as is sold under the trade name of 600 W, but when it is impossible to prevent oil of this consistency from working out of the ends of the axle and into the brake drums, a light transmis-

sion grease especially prepared by some reliable manufacturer, will give the best results.

Alemite System.

A great many cars are now being equipped with a patented lubricating system. The Alemite system in which grease is delivered to bearings under high pressure, is shown in Fig. 1. It consists of a cylinder *a*, to which is attached a 15-inch flexible hose *b*, terminating in

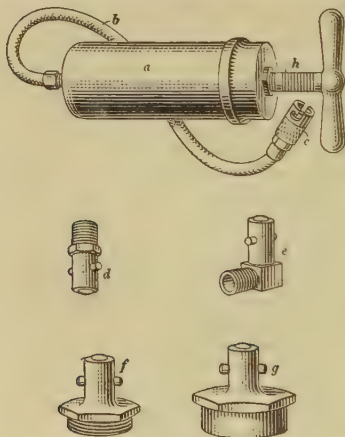


FIG. 1

a bayonet coupling *c*. Ball check nipples are shown at *d* and *e*, the latter being of the elbow type for inaccessible places. The nipples are substituted for the old grease or oil cups. Where a car is already equipped with a grease cup integral with the shackle bolt, a cap as shown in *f* or *g* is furnished.

In using the lubricator, the bayonet coupling *c* is placed over the nipple with the steel projection opposite the coupling slot and by a slight pressure forward, and a turn to the right, a tight joint is made. Screwing the plunger *h* in forces the

grease into the bearings. Because of the high pressure possible with this device, the old grease is forced out of the bearings. The system described is one of a number of systems, operating on practically the same principle, now on the market. Some of the advantages claimed for these systems are ease and cleanliness of operation, a material saving in time, and the elimination of guess work as to whether the bearings are properly lubricated or not. With such systems, there is less likelihood of neglected bearings.

ENGINE LUBRICATION SYSTEMS

The many different systems by which the moving parts of automobile engines are supplied constantly with oil while the engine is at work can be broadly divided into *splash lubrication systems*, *pressure-feed lubrication systems*, and *combined splash-and-pressure feed lubrication systems*.

In a splash lubrication system, the lower part of the crank-case contains cylinder oil into which the lower end of the connecting-rods dip at every revolution, churning the oil into a dense mist and throwing it all over the internal surfaces of the engine. There are two general divisions of this lubrication system in existence.

The first class is known as the *circulating constant-level splash system*. In this, the oil is transferred from a reservoir, in much larger quantities than is needed, into troughs placed beneath the connecting-rods, from which troughs the oil overflows back to the reservoir, whence it is sent back to the troughs again. The oil is thus continually circulated. In some circulating constant-level splash systems, individual troughs are used, one being placed under each connecting-rod; the oil reservoir is then in the bottom of the crank-case and is open at the top. In other systems, the oil reservoir, when in the bottom of the crank-case, is closed on top by a horizontal partition in which the troughs are formed, each trough having an overflow through which surplus oil flows back to the reservoir.

The other class of splash lubrication system is spoken of as the *non-circulating constant-level system*. In this system, oil is taken from a reservoir by a pump and delivered, in the right quantity, to troughs into which the ends of the connecting-rods dip. The oil reservoir may form part of the crank-case or be

entirely separate from it; the delivery of the pump is usually adjustable, and fresh oil is delivered to the splash troughs at all times, in which respect this system differs from the circulating system.

In a *pressure-feed lubrication system*, as implied by the name, the oil is supplied to the rubbing surfaces under pressure. In the strictest sense, the oil would be supplied to all rubbing surfaces under pressure; as carried out, however, oil under pressure is usually supplied only to the crank-shaft main bearings, crankpins, wristpins, and timing gearing. The oil thrown off from the crankpins is usually relied upon to lubricate the cam-shafts, cylinders, and other rubbing surfaces.

Pressure-feed lubrication systems are divided into two classes, the first one of which may be called a *low-pressure lubrication system*. In one subdivision of this class, oil lying in the bottom of the crank-case is pumped continually into an elevated tank, whence it flows under the low pressure due to the elevation of the tank through individual pipes to the various bearings, whence it drains to the bottom of the crank-case and is pumped back again to the tank. In another subdivision, no pump is employed. The oil is contained in an elevated tank and passes through adjustable sight-feeds and individual pipes to the various bearings, in some cases only under the influence of gravity, but in others under a slight pressure derived by connecting the top of the oil tank with the exhaust pipe of the engine; the used oil is not returned to the tank. In yet another subdivision, the flywheel of the engine dips into oil in the reservoir and carries it to an elevated point, whence the oil flows, partly by gravity and partly by pressure due to centrifugal force, to the bearings and cylinders.

In the *high-pressure lubrication system*, oil is taken from a reservoir, usually in the bottom of the crank-case, and delivered by a pump or pumps under pressure ranging from 3 to 30 lb. per sq. in. to the various bearings; in racing cars much greater oil pressures are often used. In present-day practice, a single pump is employed, which discharges into a manifold from which branch pipes lead to the various bearings; individual pumps for each bearing have been employed, however, in many of the older cars.

In *combined splash-and-pressure-feed lubrication systems*, many different combinations of the various forms of splash and pressure systems are possible and have been used. A common form employs pressure feed to the main crank-shaft bearings, the overflow from these bearings flowing into troughs below the connecting-rods, from which the crankpins, wrist-pins, cylinders, etc. are lubricated by splash lubrication. In another system, oil is supplied only to the cylinders under pressure; all the bearings are lubricated by the splash system. Other combinations than those enumerated here may be used.

ELECTRIC EQUIPMENT

ELECTRICITY AND MAGNETISM

ELEMENTARY PRINCIPLES OF ELECTRICITY

Electricity is the name given to the cause of all electric phenomena. The exact nature of electricity is not known; but its effects, the laws governing its action, and the methods of controlling and using it are well understood. Electricity may appear either to reside on the surface of bodies as a *charge*, or to flow through the substance or on the surface of a body as a current. *Electrodynamics* is that branch of science that treats of the action of the electric currents. The electricity used for igniting the combustible mixture, or charge, in automobile engines is in motion, and hence its discussion falls naturally under electrodynamics.

All bodies conduct electricity to some extent, and there is no known substance that does not offer some resistance to its flow. All bodies have therefore been divided into two classes: *non-conductors*, or *insulators*, which offer a very high resistance to the passage of electricity; and *conductors*, which offer a comparatively low resistance to the passage of electricity. A substance that allows current to pass freely is called a *good conductor* of electricity and its conductivity is said to be *high*.

In automobile practice, the following substances are used as conductors: Copper in wires, switches, and parts of appara-

tus; brass and bronze in parts of apparatus and machinery; iron and steel as parts of the machinery; aluminum alloy in machine parts; tin-foil in connection with induction coils; platinum or an alloy of platinum and iridium (platinoidium), as well as tungsten for the points at which the electric current is interrupted in ignition devices; and the metals, carbon, and alloys, and also solutions, in batteries.

An *insulating substance* is one that does not allow any appreciable quantity of electricity to pass through it under the condition in which it is used. The insulating materials commonly used for the electrical parts of an automobile are: India-rubber composition; silk and cotton on wires used in apparatus and for connecting them; paraffin in induction coils and to some extent on wires; hard, or vulcanized, rubber and bakelite in induction coils, magnetos, etc.; wood fiber (vulcanized or compressed into hard sheets, tubes, etc.) in the electric apparatus and around wires; mica, porcelain, and steatite, also called soapstone, in the spark plug; shellac applied as a varnish on wood and in some parts of the apparatus; dry wood, varnished; paper, varnished, in induction coils; pitch in dry batteries, and sometimes on wire. Copper wire insulated with cotton, silk, rubber, or composition of some kind is about the only wire used in the electrical circuits of automobiles, where it is employed in the ignition, lighting, and electric starting systems.

The opposition that a substance offers to the passage of a current through it is called its *resistance*. If the sectional area of a piece of a given material is uniform, its resistance is directly proportional to its length. Hence, a piece of copper wire of uniform diameter and 10 ft. long has twice the resistance of 5 ft. of the same wire; also a piece 15 ft. long has three times the resistance of 5 ft. of the same wire. If the length of the two pieces made of similar material are equal, their resistances are inversely proportional to their sectional areas. The greater the sectional area the less the resistance.

The *electric potential* of a body is its electrical condition, and is analogous to pressure in gases, head in liquids, and temperature in heat. If two connected bodies have the same electrical potential, there will be no flow of electricity from one to the other; but if there is a difference of electrical potential, electric-

ity is said to flow from the body having the higher potential to the body having the lower potential, and the rate of flow is proportional to the difference of potential.

Electricity is a condition of matter, and not matter itself, as it has neither weight nor dimensions. Consequently, the statement that electricity is flowing through a conductor must not be taken too literally; it is only another way of saying that a change, the nature of which is not fully understood, is taking place in the electrical condition of the conductor and that differences of potential are tending to become equalized.

The expression *electromotive force*, usually abbreviated to *E. M. F.*, has practically the same meaning as difference of electric potential, or electric pressure. The *E. M. F.* is the force that moves or tends to move electricity from one place to another. The practical unit of *E. M. F.* is the *volt*. An instrument used to measure electric pressure and indicate its intensity in volts is called a *voltmeter*.

An *E. M. F.* may be produced in a number of ways, of which only two, however, find an application in automobile work. These are: By dipping the ends of two strips of dissimilar materials into a liquid that has a greater tendency to act chemically on one material than on the other; the *E. M. F.* is due to chemical action or affinity between the strips and the liquid.

By magnetic induction.

Electric pressure is measured in *volts*; current in *amperes*; and the electrical resistance in *ohms*. A pressure of 1 volt will send a current of 1 ampere through a resistance of 1 ohm; also, 2 volts will send 2 amperes through the same resistance.

An instrument that indicates the number of amperes of current flowing in a circuit in which it is connected is called an *ammeter*. For use in automobile practice, an ammeter and a voltmeter are frequently combined in a single small case that is easy to handle.

If two dissimilar materials, as zinc and carbon, are partly or wholly immersed in water in which some acid has been mixed or a salt has been dissolved, and are connected by a conductor outside the liquid, chemical action will occur between the two materials and the liquid, and an electric current will flow through the liquid and the external circuit. Such a device is

known as the *voltaic*, or *galvanic*, *cell*, from its discoverers, Volta and Galvani.

The liquid, no matter what its composition may be, is called the *electrolyte*, and it must be such that it will act more readily on one plate than on the other in order to produce a difference of potential, or E. M. F., between them. The resistance of the two plates and the electrolyte is called the *internal resistance* of the cell.

The points where the wires are attached to the plates outside the liquid are the *terminals*. The one at the carbon slab is the *positive terminal*, or *electrode*, and is indicated by the plus sign (+); and the one at the zinc plate is the *negative terminal*, or *electrode*, and is indicated by the minus sign (-).

The equalizing flow of electricity that in a galvanic cell is constantly taking place from one material to the other is known as a *direct current* of electricity, and is one that always flows in the same direction, no matter how produced. An *alternating current*, on the other hand, is one that changes the direction in which it passes in a conductor regularly a definite number of times per second. Alternating current is not produced by chemical action, but is generated by mechanical means.

An *electric circuit* is a path composed of a conductor or of several conductors joined together, through which an electric current passes from a given point around the conducting path back again to its starting point. A circuit is *broken*, or *open*, when its conducting elements are disconnected in such manner as to prevent the current from flowing. A circuit is *closed*, or *complete*, when its conducting elements are so connected as to allow the current to flow. A circuit in which the conductors have come into contact with the ground, or with some electric conductor leading to the ground, is said to be a *grounded circuit*, and the contact is called an *earth*, or a *ground*. In automobile practice, a grounded circuit is one that is completed through the engine and frame of the car, the wire connected to the frame or engine being called the *grounded connection*, even though there is no connection whatever with the earth. A circuit divided into two or more branches, each branch transmitting part of the current, is a *divided circuit*; the conductors forming these branches are said to be connected in

parallel, or *multiple*. Each branch taken separately is called a *shunt* to the other branch or branches.

MAGNETS AND MAGNETISM

Natural and Artificial Magnets.—Near the town of Magnesia, in Asia Minor, the ancients found an ore that possessed a remarkably attractive power for iron. This attractive power they named *magnetism*, and a piece of ore having this power was termed a *magnet*; the ore itself has since been named *magnetite*. When a bar or a needle of hardened steel is rubbed with a natural magnet, it acquires magnetic properties similar to those of the natural magnet without the latter losing any of its magnetism; such bars are called *artificial magnets*. Artificial magnets that retain their magnetism for a long time are called *permanent magnets*. The common form of permanent magnet is a bar of steel bent in the shape of a horseshoe and then hardened and magnetized. If a piece of soft iron called an *armature*, or *keeper*, is placed across the two free ends, it prevents the magnet from losing its magnetism.

If a bar magnet is dipped into iron filings the filings will be attracted toward the two ends and will adhere there, while toward the center of the bar there is no such tendency. That part of the magnet where there is no apparent magnetic attraction is called the *neutral region*, and the parts around the ends where the attraction is greatest are called *poles*. If a bar magnet is suspended by a thread, or in some other manner, so that it can swing freely horizontally, one pole will point approximately north and the opposite pole will point south. The north-seeking pole of a magnetic needle or other magnet is known as a *north pole*, though of opposite polarity to the north pole of the earth; and the opposite end of the magnet is called a *south pole*. If the north pole of one magnet is brought near the south pole of another magnet, *attraction* takes place; but if two north poles or two south poles are brought together, they *repel* each other. In general, *like magnetic poles repel each other and unlike poles attract each other*.

All magnetic substances are not necessarily magnets; nevertheless, they are capable of being attracted by a magnet. A piece of soft iron will be attracted toward either pole of a

magnet; but when not in the vicinity of a magnet it has no defined poles, nor will it attract another piece of unmagnetized iron.

If a sheet of paper is laid over a bar magnet, and fine iron filings are sprinkled on the paper, the filings will arrange themselves in curved lines extending from the north to the south pole, as shown in Fig. 1, in which *N S* is the bar magnet. If the magnet is placed in a vertical position with the paper over one end, the filings will arrange themselves in lines extending radially in all directions from the pole *N*, as shown in Fig. 2. These invisible *lines of magnetic force*, or simply *lines of force*, acting in the directions shown, make up the *magnetic field* of a

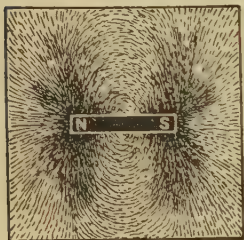


FIG. 1

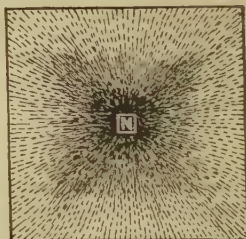


FIG. 2

magnet, or the surrounding spaces in which magnetic substances are acted on by the magnet. The lines of force as a whole may be referred to by any of the expressions *magnetism*, *magnetic induction*, or *magnetic flux*.

The *direction of the lines of force* is assumed to be from the north to the south pole through the air or other surrounding medium, and from the south to the north pole through the magnet, thus completing the *magnetic circuit*. Lines of force can never intersect one another. The permanent magnets used in automobile ignition are generally **U** shaped, as shown in Fig. 3. The magnetic field is much stronger in the space between the poles than in any other region outside of the magnet itself. The direction of the magnetic lines of force is

indicated by the dotted lines and arrowheads. The magnetic lines of force are assumed to flow from the north pole to the south pole.

Electromagnets.—If a piece of insulated copper wire is wrapped around an iron nail, or in fact, around any piece of iron or steel, and current is sent through the wire, the nail will become a magnet while the current is passing and cease to be one when the current is broken. The coil of wire together with the electrically magnetized nail forms what is known as an *electromagnet*. The wire winding is called the *magnetizing coil*, or the *exciting coil*, or a *solenoid*, and the iron or steel (nail in this case) is the *core*. One end of the nail will be a north magnetic pole and the other end a south magnetic pole. An electromagnet loses nearly all its magnetism as soon as the current ceases to flow. A small amount, known as *residual magnetism*, is usually retained, the amount being greater in the cores of steel or hard iron than in the soft ones.



FIG. 3

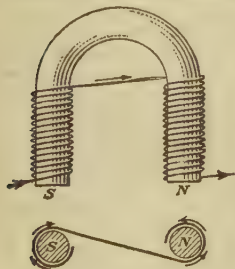


FIG. 4

the other a south pole S. The part of the iron bar connecting the cores at the back end is called the *yoke* of the magnet.

Electromagnetic induction is the production of E. M. F. in a conductor or a number of conductors by relative motion between the conductors and a magnetic field in their vicinity. The strength of an induced E. M. F. is proportional to the quickness of the relative motion and to the strength of the magnetic field. The effect of inserting a magnetized piece of steel, as, for instance, a permanent bar magnet, in a coil or withdrawing it from the coil, is the same as would be produced by putting one coil, through which a current is flowing, within another coil or by withdrawing it. In each case a current is induced in the outer coil.

PRIMARY AND SECONDARY BATTERIES

DEFINITIONS

When a number of cells are connected together, as is customary in practice, they form an *electric battery*. In commercial usage, however, the term battery is indiscriminately applied both to a group of electrically connected cells and to a single cell; a single cell is also known as a *battery cell*.

The electric batteries used for ignition purposes are of two distinct classes: *primary batteries* and *secondary, or storage, batteries*; secondary batteries are also known as *accumulators*. The primary battery will deliver electric current as soon as its parts are assembled, but with the storage battery, electricity from some source of supply must be stored in it before it becomes electrically active. The primary batteries used in automobiles are known as *dry batteries*, because they have no free body of liquid to flow and splash. Primary batteries having a free body of liquid are called *wet batteries*. Although serviceable for ignition purposes with stationary gas and gasoline engines, battery cells of the wet type are not suitable for use on automobiles, because usually they are easily broken. Besides, they are too bulky, and the motion of the car causes the liquid electrolyte to be thrown out of the jar. On the other hand, some wet cells have a much longer life than the dry type of cell commonly employed.

The chemical action in a primary cell or battery required to produce the electric current liberates hydrogen gas, which collects as small bubbles on the carbon and prevents intimate contact between the carbon and the electrolyte, and the cell is then said to be *polarized*. This polarization reduces the amount of chemical action, and consequently less current is produced. If the electric circuit is broken and the battery is left standing on open circuit for some time, the battery will recuperate to some extent while resting, by *depolarizing* itself. This condition is also accomplished by surrounding the carbon plate with some substance with which the free hydrogen can combine. There are many kinds of depolarizing primary cells, some with solid and some with liquid depolarizers.

PRIMARY CELLS AND CONNECTION

Dry Cells.—Fig. 1 shows a section of a *dry cell* such as is used for automobile ignition. The carbon rod *c* is placed in the center, and the zinc forms the enclosing cup, or can, *a*. The can is lined with absorbent paper that is completely saturated with sal ammoniac and zinc chloride dissolved in water; next to the paper is a thin layer *d* of white paste. The space between the carbon rod and the lining of the cup is filled, except at the top, with the depolarizer *m*, which is a mixture of powdered carbon or coke and manganese dioxide. The cell is sealed water-tight with pitch or some similar substance, which fills the space above the depolarizer, and is permanently wrapped, except over the top, with pasteboard and paper, to prevent metallic contact with other cells in a battery. The positive terminal is at the center of the top, and the negative terminal is a binding screw attached to the top edge of the zinc. The cells generally used for automobile ignition are $2\frac{1}{2}$ in. in diameter and 6 in. long. Other dry cells similar in general appearance to

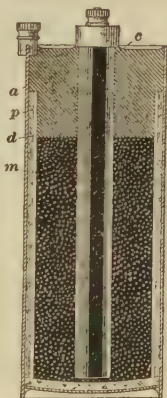


FIG. 1

this but differing in some of the materials employed are extensively used for ignition.

Battery Connections.—By connecting two or more cells together, more current can be obtained. Evidently, two cells



FIG. 2



FIG. 3

can be connected in two ways: Either the positive (+), or carbon-plate, terminal of one cell can be connected to the negative (-), or zinc-plate, terminal of the other (carbon to zinc), as in Fig. 2, which shows a *series connection*; or similar terminals can be connected together, as in Fig. 3, which shows *multiple, or parallel, connection*.

If two or more cells are connected in series, as in Fig. 2, the positive terminal of one and the negative terminal of the other become the terminals of the battery. The voltage of the battery is measured between the battery terminals. When the circuit is open, as shown, the voltage of the two-cell series-connected battery is twice that of one cell, provided the cells are alike or have the same voltage. In any case, the battery voltage of series-connected cells on open circuit is equal to the sum of the voltages of the cells.

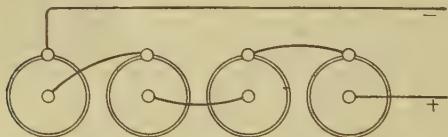


FIG. 4

If one of the cells in a series battery is reversed, as shown in Fig. 4. the voltage on the open circuit will be reduced to the same extent as if two cells had been removed from the prop-

erly connected battery of the same number of cells. The pressure of the reversed cell counteracts the pressure of one of the properly connected cells. Primary cells in a series battery are not injured by the reversal of one or more of them.

If two or more cells are connected in parallel, carbon to carbon and zinc to zinc, the carbon side will be the positive terminal and the zinc side the negative terminal, as shown in Fig. 3. The voltage, or pressure, remains the same as for one cell. The internal resistance of the battery is reduced below that of one cell, because there is a greater sectional area of battery materials for the current to pass through. Therefore, the total resistance of the complete circuit, external plus internal, is reduced by increasing the number of parallel-connected cells. As the pressure remains unchanged, the ratio of the pressure to the total resistance is increased, and this means an increase of current. The internal resistance of two similar cells in parallel is half that of one cell; of four similar cells in parallel, one-fourth that of one cell, and of six similar cells, one-sixth that of one cell. All the cells of a parallel-connected battery should be of the same make, or at least made of the same materials, and should have the same voltage. It is best to have all of them just alike. If one of the cells in a parallel-connected battery is reversed, as shown at *a*, Fig. 5, the current will flow, as indicated by the arrows, until the

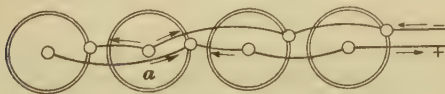


FIG. 5

cells properly connected in parallel are exhausted. The reversed cell corresponds in a way to a closed external circuit, which, with dry cells, is of small, or low, resistance. Hence, the external circuit will receive practically no current. If cells giving different pressures are connected in parallel, the action will be similar to that occurring when one of the cells in a parallel-connected battery is reversed.

If two series batteries of the same number of like cells are connected in parallel, which is called a *multiple-series* and also a *series-parallel connection*, as in Fig. 6, the pressure will be the same as that of one series. Each series of cells may be considered as a unit and may be dealt with as a single cell having a pressure and a resistance equal to that of the series. The internal resistance of a battery of two series sets, each set of the same number of cells, is one-half that of one set, or unit. For three series of four cells each, the internal resistance is one-third that of one set having four cells in series. When there are as many series as there are cells in each series, the internal resistance of the battery is the same as that of one cell.

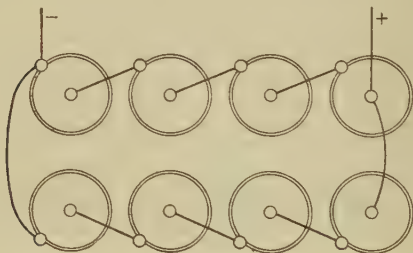


FIG. 6

Each series of cells forming a unit should have the same number of cells; otherwise, the higher pressure of the series having the greater number of cells will force the current back through the series having the smaller number and exhaust the cells in the larger series. A reversed cell in a parallel-series battery has much the same bad effect as a reversed cell in a single parallel arrangement of cells.

Increasing the number of good cells in an ignition circuit will increase the current in the circuit, if the cells are properly connected. The total E. M. F. is increased as the number of cells in series is increased; or, the internal resistance of the battery is decreased as the number of sets of cells in parallel is

increased. In both cases, however, the resistance of the external circuit remains unchanged. Hence, the current is increased in the first case because the E. M. F. applied to the circuit increases faster than the internal resistance of the battery increases the total resistance of the circuit. In the second case, the E. M. F. and external resistance remain constant, but the internal resistance, and hence the total resistance, of the circuit is decreased. The switch for connecting two series batteries to an external circuit should be made and located so as to break the connections in such a manner, when opened, as to make it impossible for any current to flow between the different sets of cells. Exhaustion of the battery when not in use is

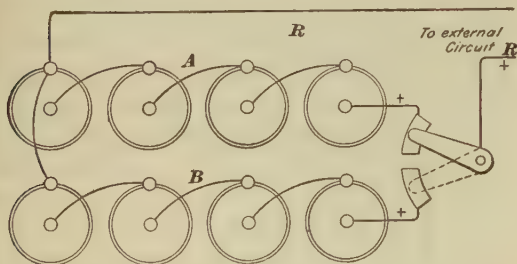


FIG. 7

thus prevented. Fig. 7 shows the correct method of connecting a switch to a battery consisting of two series of cells. The wires *R* lead to the external circuit. When the switch is closed in the position shown, only series *A* is brought into operation, and when the switch is moved to the dotted position, only series *B* is put into the circuit and *A* becomes idle.

SECONDARY, OR STORAGE, BATTERIES

Lead-Plate Batteries.—The type of storage battery that is in general use in automobile work is the *lead-plate battery*, so named on account of the materials used in making up the *active elements*, between which the chemical action in the

battery takes place. The active elements in the lead battery are lead and diluted sulphuric acid, the latter being the electrolyte.

Storage batteries for ignition purposes are now usually constructed so as to be capable of supplying current for the electric lighting and cranking of the automobile as well as for the ignition. The current is produced by means of a chemical action that takes place between the active elements, after a certain chemical condition has been reached by first passing a current through the battery. The lead in the battery is in the form of paste and is pressed into *plates* so as to make the surface of the active material exposed to the sulphuric acid as large as possible. The framework of the plate, which gives it the necessary rigidity, is usually a *grid* with openings or pockets for holding the lead and is made of an alloy of lead, which is a combination of lead and some other metal. One group of plates forms the *positive group*, to which the positive terminal is attached, and another group forms the *negative group*, to which the negative terminal of the battery is connected. The plates of the two groups are separated from each other by *separators*, made of thin strips of wood or rubber, and are immersed in the electrolyte, which is contained usually in a hard rubber jar known as the *containing jar*. The lead in the positive plates is in the form commonly known as *red lead* and is of a dark brown color, while that in the negative plates is a compound of lead known as *litharge* and is gray in color after being formed into a plate.

As in the primary battery, the unit of the storage battery is the cell, which is composed of a positive group, a negative group, and the necessary separators. A battery consists of two or more cells connected in series, that is, with the positive terminal of one cell connected to the negative terminal of the adjacent cell, and so on, leaving a free positive and negative terminal as the battery terminals.

The construction of the ordinary type of storage battery is shown in Fig. 8, which shows one cell of the LBA battery cut in two crosswise, exposing to view the various parts. The elements of each cell are contained in a semiflexible rubber jar *a* that carries the plates *b* and *c* on supports *d* and thus

provides a space in the bottom of the jar for any sediment from the plates. Like plates, that is, either the positive or the negative plates of a cell, are connected at each end, as shown at *e* and *f*, and a terminal from each set of plates is brought up through the top of the battery. In the cell shown, one terminal *g* is a battery terminal while the other terminal *h* is connected to the adjoining cell. When the cell is in working condition, the electrolyte, which consists of sulphuric acid and water, should fill the jar high enough to cover the plates, or, when the cell is freshly filled, up to the first cover *i*. Provision

is made by means of a removable plug *j* for the addition of water at regular intervals as the water in the electrolyte evaporates. The plug contains a small hole that serves as a vent, through which liberated gases may escape. An expansion chamber *k* is provided in the upper part of the cell for changes in the volume of the electrolyte during charging or discharging. A top cover *l* of polished hard

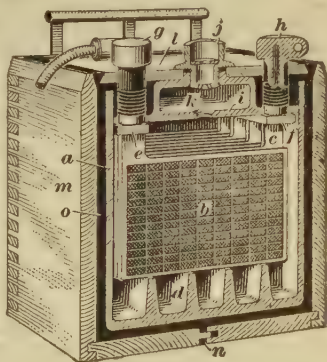


FIG. 8

rubber is placed over the expansion chamber and sealed acid-tight. The outer wooden box *m* is provided with an expansion joint *n* to allow for any changes in its volume. A plastic sealing compound *o* surrounds the rubber containing jar between it and the box and acts as a cushion. The wood separators, which are placed between the adjacent plates, are hidden from view by the plates. These prevent the positive and negative plates from touching each other and thus short-circuiting the cell and rendering it inoperative. In some storage batteries additional perforated hard rubber separators are used.

A group of plates, with separators between them and placed in a jar containing electrolyte, constitutes a cell. Any number of cells may be connected in series to form a battery, but for ignition and electric lighting and starting purposes, storage batteries usually contain 3, 6, 8, 9, or 12 cells, depending upon the nature of the electric system. The nominal voltage of a storage battery is usually taken as 2 volts per cell, this being about the average voltage generated between the fully charged and the fully discharged conditions. For instance, the nominal voltage of a 3-cell storage battery is 6 volts, although the actual voltage when fully charged is approximately 6.8 or 6.9 volts. Storage batteries are generally designated by their nominal voltages, as, for instance, a 6-volt battery, a 12-volt battery, a 16-volt battery, and so on.

The *capacity* of a storage battery is usually stated in units called *ampere-hours*. An ampere-hour is a current of one ampere maintained for 1 hr.; hence, the capacity of a battery in ampere-hours is found by multiplying the number of amperes of current delivered by the number of hours during which the current passes. For instance, a storage battery that is capable of discharging 5 amperes of current continuously for a period of 12 hr. has a capacity of $5 \times 12 = 60$ amp.-hr.

Edison Nickel-Iron Battery.—In what is known as the *Edison nickel-iron storage battery*, invented by Thomas A. Edison, the active material of the positive plate is nickel peroxide, and that of the negative plate is finely divided metallic iron. The electrolyte is a dilute solution of potassium hydroxide, or caustic potash. A small quantity of lithium hydroxide is added to the electrolyte to improve the capacity of the battery. The absence of acid in the electrolyte makes possible the use of steel in the construction of the containing jar and the plates. The Edison battery is chiefly adapted to the propulsion of electric vehicles but may also be used for the electric lighting, starting, and ignition of gasoline automobiles.

The positive plate of the nickel-iron cell consists of a number of hollow tubes of perforated steel, nickel-plated, supported vertically in a nickel-plated steel grid. The active material consists of nickel peroxide and flake nickel tamped into the tube in alternate layers, the flake nickel being added

to increase the conductivity. The negative plate consists of rectangular pockets of perforated nickel-plated steel supported in a nickel-plated steel grid, the pockets being filled with finely divided iron oxide, which is reduced to metallic iron by the initial charge. The containing jar is made of nickel-plated sheet steel, corrugated to give added stiffness.

Each cell is assembled in the same manner as a lead-plate cell. The positive and negative plates alternate, with hard rubber separators between them, the group resting on hard rubber bridges. The electrolyte should completely cover the plates.

The voltage of a nickel-iron battery is about 1.5 volts per cell when fully charged, though when discharged it quickly drops to 1.3 volts and the average voltage during discharge is 1.2 volts per cell. A nominal six-volt battery, then, requires five cells. Nickel-iron batteries should preferably be charged at constant current, a charge of 7 hr. at the 5-hr. rate being recommended by the manufacturers. Overcharging at this rate will slightly increase the capacity of the battery.

The state of charge of an Edison storage battery cannot be found by the specific gravity of the electrolyte, as this does not change. Neither is the cell voltage or the amount of gassing a reliable guide. The only practicable method is to measure the output and input in ampere-hours, either by noting the rate in amperes and the time or by means of an ampere-hour meter.

Charging of Storage Batteries.—A direct current must always be used for charging the storage battery. In case only an alternating current is available an alternating-current rectifier of some kind must be used. When charging a battery, a test should be made to make sure that the positive plates are connected to the positive terminal of the charging circuit. A simple way to make this test is to attach two wires to the source of current supply and then dip their free ends into water made slightly impure by the addition of a salt or an acid; sulphuric acid, sal ammoniac, or common salt will serve the purpose. The immersed wire end that gives off most bubbles is the one to be connected to the negative terminal of the storage battery; the other wire should go to the positive terminal of the storage battery. The polarity of the storage

battery terminals may also be determined in the foregoing manner.

The battery should be charged not more rapidly than at a rate determined by its capacity in ampere-hours, the charging current, in amperes, being equal, for an ordinary battery, to the ampere-hour capacity divided by 8. Thus, a 60 amp.-hr. battery should be charged at 7.5 amp. or an 80 amp.-hr. battery at 10 amp. Another, and perhaps better, rule is to charge at a rate not exceeding one-sixth the ampere-hour capacity, and then maintain this rate by gradually cutting out resistance until the voltage reaches 2.4 or 2.5 per cell, when the cells begin to gas. The charging current should then be cut down to one-twentieth the ampere-hour capacity until the cells again gas freely, indicating a full charge.

If the battery is charged from a direct-current, incandescent-light circuit, there must be used in series with the battery a resistance sufficient to absorb the greater portion of the voltage of the charging circuit. For this purpose, a bank of lamps is generally employed. As the internal resistance of the battery is so small as to be almost negligible, it follows that a 110-volt lamp must be used for a 110-volt current.

Wiring connections for charging storage batteries from direct-current lighting and power circuits are shown diagrammatically in Fig. 9. Connections to a 110-volt lighting circuit are shown in (a). A double-pole switch *a*, with fuses *b*, is connected between the mains and the battery, as shown. In series with the battery *c* are a number of lamps. It is advisable to connect an ammeter *d* in circuit, though this is not absolutely necessary.

The number of lamps required depends on the line voltage and on the charging rate of the cells. If the line pressure is 100 to 120 volts and only three or four cells are to be charged with a current of 5 amp., five 32-c. p. carbon lamps requiring 1 amp. each, connected in multiple, as shown in (a), will be sufficient. If 16-c. p. carbon lamps requiring $\frac{1}{2}$ amp. each are used, it will be necessary to connect ten in parallel. With a 220-volt circuit, there will be required twice as many lamps as with the 100-volt circuit, the second set of lamps being placed in series with the first. If the line pressure is 500 volts,

it will be necessary to connect twenty-five 32-c. p. carbon lamps in five rows of five lamps in series in each row, as shown in (b), or fifty 16-c. p. carbon lamps in ten rows, five lamps in series in each row. In case it is convenient to charge at a

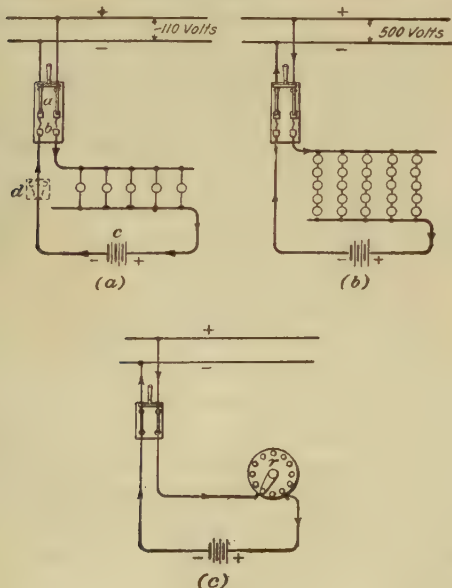


FIG. 9

lower rate, fewer rows of lamps will be needed, but the time for charging will be proportionately increased.

While incandescent lamps are usually made for a voltage of approximately 110 volts, they are also made for a large number of other voltages. Wherever lamps requiring the same

voltage as that of the charging current can be had, they should be connected simply in parallel.

When tungsten filament lamps or carbon lamps of other than 32 or 16 c. p. are used as resistance, the number of lamps required may be found by multiplying the charging rate in amperes by the line voltage and dividing the product by the watt consumption per lamp. For example, if 40-watt lamps are to be used, with a voltage of 110 and a desired amperage

of 8, the result would be: $\frac{8 \times 110}{40} = \frac{880}{40} = 22$ lamps.

The methods just given for securing the necessary resistance are those actually used in practice, and they are accurate enough for this purpose.

To charge a low-voltage battery, such as an ignition storage battery, from a 500-volt direct-current circuit is a very inefficient method. The high voltage makes it somewhat dangerous and requires that very good insulation be used throughout the circuit.

Lamps form a convenient resistance, as they are easily obtained, but an adjustable rheostat is frequently used, as shown at *r*, Fig. 9 (*c*). The amount of resistance required in the rheostat may be calculated by subtracting the approximate voltage at which the storage battery should be charged from the charging-line voltage, and then dividing this difference by the desired charging current.

Care of Lead-Plate Batteries.—A storage battery that is in service should be inspected at least every 2 weeks and in warm weather somewhat oftener, and chemically pure, that is, distilled, water added to the electrolyte. The solution should never be allowed to get below the top of the plates. Only pure water, free of mineral matters, should be used in a storage battery. Acid should only be added when a quantity of the electrolyte has been spilled.

A storage battery that has become weak through a continuous undercharging may be restored to its normal capacity by putting it on a long charge at a very low rate. The specific gravity of the electrolyte should be tested frequently during a long charge, and the charging should be kept up till the gravity ceases to rise. A battery that is to stand idle for any

length of time should first be fully charged and then given a freshening charge at least once a month during the period of idleness. Where the battery is used in connection with a generator, the recharging can be done by running the engine and thus charging from the generator. If this is not convenient, the battery can be charged from an outside source. Provided it is absolutely impossible to give the battery these freshening charges by any means, the battery may be allowed to stand without charging during the idle period if the specific gravity of the electrolyte registers from 1.270 to 1.290 at the time the car is laid up, but this method is not advisable where periodic charges can be made.

The wires should be disconnected from the battery during the time it is out of service, as a slight leak in the wiring would otherwise discharge the battery.

When a battery has been laid up for several months, it is advisable to give it a thorough charge before putting it in service again. This is absolutely necessary if no periodic charges have been made.

When a battery is stored away for the winter, it should be put in a cool place but not allowed to freeze. A battery that is completely discharged will freeze at about 20° above zero, F. A fully charged battery will not freeze at ordinary temperatures; electrolyte having a specific gravity of 1.160 will freeze at 0° , that having a specific gravity of 1.210, at 20° below zero, and that having a specific gravity of 1.260, at 60° below zero.

While a battery is discharging, lead sulphate is formed on both the positive and negative plates and is converted into lead peroxide on the positive and spongy lead on the negative plate during the following charge. However, if the battery is allowed to stand in a discharged condition for any length of time, the lead sulphate will harden, causing what is known as *sulphating*. This condition of the battery results in loss of capacity, buckling of the plates, or shedding of the active material.

Sulphating may be remedied by giving the battery a long charge at a low rate, when the sulphate will be loosened and the plates restored to their usual condition.

BATTERY AND GENERATOR IGNITION

INDUCTION COILS

Fundamental Principles.—In modern automobile ignition, the spark for igniting the combustible mixture in the engine cylinder is produced by causing a current of high voltage to jump across a space, or gap, between two metallic conductors, thus forming an arc, or spark, across the space. The current may be obtained from either a dry-cell battery, a storage battery, a direct-current generator, a low-tension magneto, or a high-tension magneto. When current is obtained from any source other than a high-tension magneto, an *induction coil* must be used to increase the voltage sufficiently to cause an electric spark to jump the air space. An induction coil is also called a *transformer coil*.

An induction coil, in the form commonly used in ignition systems, consists of two windings of insulated copper wire wound on a core that is made up of a sheaf, or bundle, of soft iron or steel wire.

Two elementary induction, or transformer, coils are shown in perspective in Fig. 1, which illustrates the general method of construction of such coils. The two coils shown differ only in the disposition of the ends of the windings and like parts are lettered the same in the two views. The soft iron or steel core is shown at *a*. About this is wound the inner winding *b*, known as the *primary winding*, which is made up of a comparatively few turns of coarse wire wrapped with cotton or silk thread for insulating it. The outer winding *c* is known as the *secondary winding* and is made up of many turns of fine wire, also insulated. In practice, the core is surrounded by some insulating material, usually in the form of a cylinder, or tube, between the core and the windings.

The induction coil shown in Fig. 1 (*a*) is called a *four-terminal coil*. The two windings *b* and *c* are not connected in any way and the two ends of each are the terminals of the coil, making four terminals in all. The ends *d* and *e* of the primary winding are the *primary terminals* and the ends *f* and *g* of the secondary winding are the *secondary terminals*.

A *three-terminal coil* is one in which the primary and secondary windings are joined at one end and brought out in a common terminal, as shown at *d* in Fig. 1 (b). The three terminals to such a coil are the common terminal *d* and the free ends *e* and *f* of the two windings. The end *e* of the primary winding is the primary terminal, the end *f* of the secondary winding is the secondary terminal, and the common terminal *d* is the *primary-secondary terminal*. Both high-tension and low-tension current passes through the primary-secondary terminal *d*. However, this does not interfere with the operation of the coil, for two

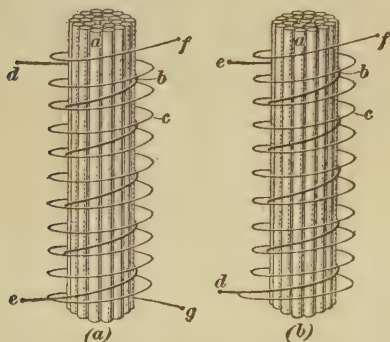


FIG. 1

different circuits may have a common conductor and the current in each circuit will not have any effect on that in the other.

If a current passing through the primary winding of an induction coil is suddenly interrupted, or stopped, an electromotive force will be set up, or induced, in the secondary winding. This induced electromotive force will set up a current in the secondary winding, provided it is connected in a closed circuit. Also, if a current is suddenly sent through the primary winding, an electromotive force will be set up in the secondary,

but it will be much lower than that set up by interrupting the current.

In electric ignition systems making use of an induction coil, the circuit in which the primary winding is connected is known as the *primary, or low-tension, circuit* and the current in this circuit is the *primary, or low-tension, current*. In like manner, the circuit in which the secondary winding is connected is the *secondary, or high-tension, circuit* and the current in it is the *secondary, or high-tension, current*.

With the ordinary ignition coil used with 6-volt electric systems the voltage of the primary current is rarely more than 9 volts, while that of the secondary current approximates 20,000 volts. The number of turns of wire in the primary winding is usually from 200 to 300 and the number in the secondary winding is from about 1,500 to 2,000. The insulation on the windings of an induction coil does not interfere with its operation, as the magnetic lines of force readily penetrate ordinary insulating material. Induction coils are most frequently, but not always, built for 6 volts.

The Electric Condenser.—When the primary current of an induction coil is interrupted by breaking the primary circuit, the current tends to continue across the gap thus formed, and as a result sparking, or arcing, occurs at the break, and the contact points of the device used for breaking the circuit are burned and destroyed. In order that this arcing and burning may be lessened and the primary current stopped as abruptly as possible, a device called a *condenser* is used in connection with every induction coil and this device absorbs the excess energy or momentum of the current when the break occurs.

The electric condenser is made up of a number of sheets of tin-foil and sheets of some insulating material, usually paraffined paper, placed together alternately, so that adjacent sheets of the tin-foil are insulated from each other by the paper. All the alternate sheets of tin-foil are connected by a conductor, and all the remaining tin-foil sheets by another conductor, forming the two *sides* of the condenser. In order to serve its purpose, the two sides of the condenser are connected to opposite sides of the point where the primary circuit is broken.

The action of the condenser in lessening arcing at the contact points of the circuit-breaker causes the current in the primary winding of the induction coil to stop more suddenly and thus a higher electromotive force is induced in the secondary winding and a bigger and hotter spark is formed at the spark gap in the secondary circuit.

The condenser has no effect when the circuit is being closed, or during the time that it continues closed, as the condenser is merely short-circuited by the circuit-breaker.

The amount of electrical energy that a condenser will hold depends on the size of the plates, and condensers are, therefore, made in various capacities to suit the ignition systems for which they are designed.

Electric condensers are made either flat or curved, depending on the method of carrying them. They are built up by two different methods and are known as *flat condensers* and *rolled condensers*, according to the method of construction.

TYPES OF INDUCTION COILS

Classification.—Induction coils are classed as *vibrator induction coils* and *non-vibrator induction coils*. In the first, the device by means of which the circuit is opened and closed is operated by the coil itself through electromagnetic attraction; this device is known as a *magnetic vibrator*. With the second class of induction coils, the primary circuit is interrupted by means of a device that is entirely separate from the coil itself; this device is known as a *circuit-breaker*, or *interrupter*. The circuit-breaker is driven from some moving part of the engine, such as the cam-shaft, or from the direct-current generator or the magneto, depending on the design of the electric system.

Vibrator Induction Coils.—The principle of operation of the vibrator type of induction coil is illustrated in Fig. 2. The vibrator *a* is a tempered steel spring carrying a platinum-ended contact point *b* that is in line with a similar point *c* on a stationary bracket *d* attached to the box or casing containing the coil. The vibrator is anchored at *e* in such a way that the contact points *b* and *c* are ordinarily closed, as shown. The primary winding is connected in the battery circuit in such a manner that the contact points form a part of the primary

circuit. Hence, if these vibrator contacts are rapidly opened and closed, the primary circuit is likewise rapidly opened and closed, thus quickly stopping and starting the primary current and inducing a high-tension current in the secondary winding. The condenser *f* is connected around the contact points.

With the primary circuit closed, the path of primary current in Fig. 2 is from the positive terminal of the storage battery *g* to the bracket *d*; through the bracket *d*, contact points *c* and *b*, and vibrator *a*, as indicated by the dotted

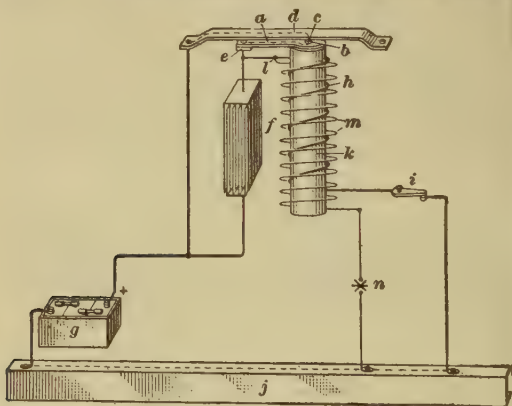


FIG. 2

lines; through the block *e*, by way of a wire connection to the primary winding *h* of the induction coil; through the primary winding *h* and the switch arm *i* to the ground *j*; through the ground, as indicated by the dotted line, and the wire connection to the negative terminal of the battery. The current through the primary winding *h* magnetizes the soft-iron core *k*, which attracts the vibrator *a*, separating the contacts *b* and *c*, and breaking the circuit. This immediately stops the current. when the core again becomes demagnetized and allows the vibrator

to spring back to its original position, once more closing the circuit. The operation of the vibrator is very rapid, so that the circuit is opened and closed a great many times a second and the current induced in the secondary winding is in rapid pulsations.

Since in the three-terminal coil one end of the primary winding is connected to one end of the secondary, it follows that the same path must serve in some places for both primary and secondary current. In the coil shown, the connection between the two windings is made at *l*. The path of the high-tension current is from the secondary winding *m* across the spark-plug gap *n* to the ground *j* and back to the secondary winding by way of either the battery and vibrator or the switch *i* and primary winding.

When a vibrator induction coil is used for inducing the secondary current, the spark produced at the spark gap in the secondary circuit is in reality a very rapidly occurring series of sparks instead of a single spark. This series of sparks is called a *shower spark*, one spark occurring for each break made by the vibrator.

When vibrator induction coils are used with multicylinder engines, it is the common practice (to which there are exceptions, however) of using one coil for each cylinder.

Master Vibrator.—Instead of providing each coil with a vibrator, sometimes a single vibrating device called a master vibrator is used for a number of coils. The master vibrator is operated by an electromagnet having a single winding, which is connected up to the low-tension windings of all of the induction coils. The master vibrator then operates for each coil, giving exactly the same vibrator action in each case and at the same time doing away with the necessity of separate vibrator adjustments for each coil. The induction coils with which the master vibrator is used either have no vibrators or have had the vibrators short-circuited by screwing down the contact points tight, or by shunting across the vibrator with a piece of copper wire.

Non-Vibrator Induction Coils.—Since the advent of the electric starter and the consequent increased use of the storage battery and direct-current generator for supplying current

for automobile-engine ignition, the plain induction coil having no vibrator has come more and more to be used to produce a high-tension current. When such a coil is used the primary current is interrupted either by a mechanically operated circuit-breaker, or interrupter, or by means of an ignition relay.

BATTERY AND GENERATOR IGNITION SYSTEMS

INDIVIDUAL VIBRATOR COIL SYSTEM

There are two methods by which a spark may be produced by an electric current, giving rise to two general classes of ignition systems, namely, the *make-and-break*, or *low-tension*, system, and the *jump-spark*, or *high-tension*, system.

The make-and-break system has not been fitted to automobile engines for many years, although it is quite widely used for stationary internal-combustion engines.

In the jump-spark system, the spark is produced by forcing a current of high voltage to jump across an air space between two conductors, thus forming an arc, or spark, across the space. The device containing the air space is called a *spark plug*. In practice, the spark plug is so located that part of it extends into the combustion chamber of the cylinder and the spark is produced in the cylinder.

In the systems of ignition used on the earlier automobiles, the dry-cell battery was the usual source of current, induction coils of the vibrator type being used to raise the current to the required voltage.

Very few makes of cars at present are fitted with individual coils for each cylinder; the best known example of this kind of an ignition system is found in the model T Ford car, which employs individual vibrator coils and a low-tension high-frequency alternating-current magneto as a regular source of current, with dry cells (to be fitted by the purchaser) as an emergency source.

An individual vibrator coil ignition system is shown diagrammatically in perspective in Fig. 1, applied to a four-cylinder engine. In an individual-coil system, there is one coil for

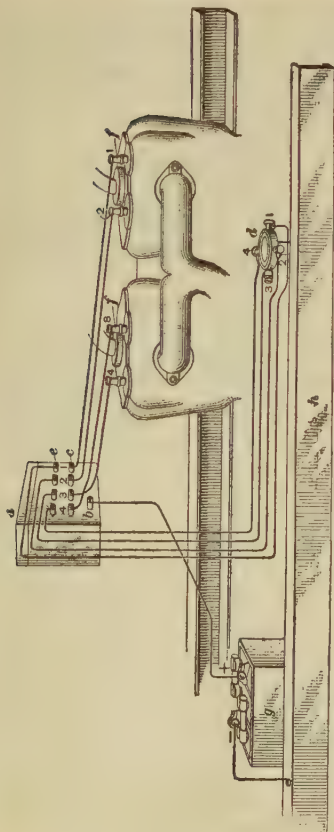


FIG. 1

each engine cylinder; hence, in this system there are four coils of the vibrator type. These are of the three-terminal form and are enclosed in a coil box *a*, the battery terminal *b* being common to all of the coils. The primary terminals *e* are connected up to the four terminals of a timer *d*. The secondary terminals *c* are connected to the four spark plugs *f*.

As the arm of the timer revolves, it makes contact successively with the contact pieces, thus connecting each induction coil in the primary circuit in its turn. As each coil is connected in the circuit, a high-tension current is induced in its secondary winding by the action of the vibrator, and a spark is produced

at the spark plug to which that particular coil is connected. For instance, with coil number 2 connected in the circuit, a spark is created in cylinder number 2. The path of the primary current under this condition is from the positive terminal of the storage battery *g*, to the coil-box terminal *b*, through the primary winding of induction coil number 2, to contact piece number 2 of the timer *d*, through timer *d* to the ground *h*, and back to the negative terminal of the battery *g*. The path of the secondary current is from the secondary winding of the induction coil through the secondary terminal number 2 to spark plug number 2, and back to the coil by way of the engine frame and battery or the engine frame and timer. The firing order of the engine shown is 1-2-4-3.

NON-VIBRATOR COIL SYSTEMS

A typical battery ignition system, making use of a non-vibrator induction coil with a mechanically operated interrupter for breaking the primary circuit, is shown diagrammatically in Fig. 2. The storage battery is shown at *a*; the switch at *b*; the induction coil, with part of the casing removed, at *c*; the interrupter, or circuit-breaker, at *d*; the distributor, which is a device for sending the high-tension current to the various cylinders, at *e*; the spark plugs at *f*; and the engine cylinders at *g*.

The interrupter mechanism is operated by a cam *h* that in this particular case has as many lobes as there are engine cylinders. As the cam rotates, each lobe strikes the interrupter lever *i*, thus bringing the contact points *j* and *k* together and then quickly separating them. The interrupter is connected in the primary circuit in such a way that the circuit is closed only when the contact points are closed; hence, each time these points are closed and opened, the primary circuit is closed and opened and a high-tension current is induced in the secondary winding of the induction coil.

With the interrupter joints closed, the path of the primary current in Fig. 2 is from the positive terminal of the storage battery *a*, through the switch *b*, through the primary winding of the induction coil *c*, to the interrupter *d*, and through the contact points and interrupter lever to a ground *l*, from which the current returns to the negative terminal of the battery.

At the instant that the primary circuit is broken, the path of the high-tension current is from the secondary winding of the induction coil through the secondary terminal *m* to the central terminal of the distributor *e*, from the distributor to the proper spark plug, and by way of the engine frame and ground to the grounded connection *n* of the induction coil.

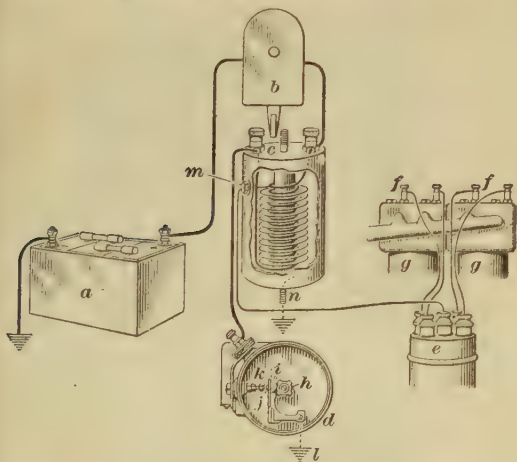


FIG. 2

The distributor *e* consists of a rotating arm or rotor that constantly makes electrical connection with the central terminal and also makes electrical connection with the outer terminals as it rotates. By means of this device, the high-tension current induced in the single induction coil is sent to each of the four spark plugs in turn. In practice, the interrupter and distributor are driven from the same shaft, the interrupter being located directly beneath the distributor. They are shown separately here in order to make clear their uses.

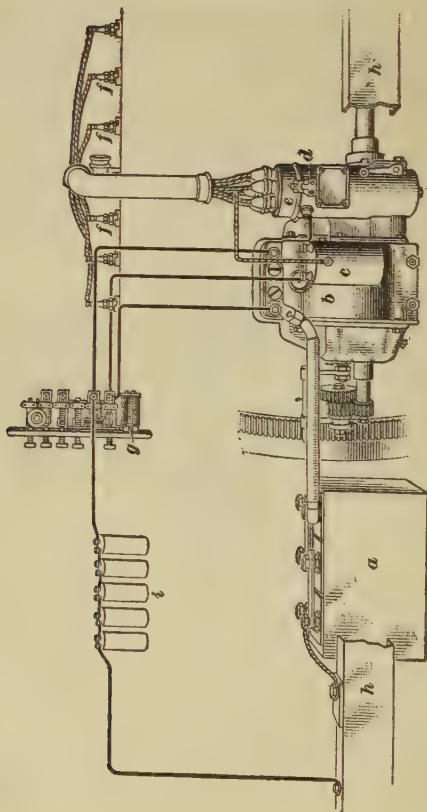


FIG. 3

A Delco dynamo-and-storage-battery ignition system, making use of a single non-vibrator induction coil and a high-tension distributor, is shown in Fig. 3. The storage battery is shown at *a*, the motor generator at *b*, the non-vibrator induction coil at *c*, the interrupter at *d*, the high-tension distributor at *e*, the spark plugs at *f*, the switch at *g*, the frame of the car, or ground, at *h*, and a dry-cell battery for reserve ignition at *i*.

When the engine is running the motor generator operates as an electric generator, and, in combination with the storage battery, furnishes current for the ignition system and electric lights. It is used as a motor when it is desired to crank the engine, in which case the current necessary for operating it is derived from the storage battery. At low speeds, the storage battery furnishes current for the ignition, while at ordinary speeds the generator furnishes the current and also keeps the storage battery charged. By means of the switch *g*, ignition from the storage battery and generator may be cut out and the dry cells *i* made to furnish the current. This forms what is known as a *dual system of ignition*. The switch is also used to turn on and off the various electric lights on the car.

The operation of the system shown in Fig. 3 is exactly like that shown in Fig. 2. A high-tension current is induced in the secondary winding of the induction coil by the action of the interrupter, and this current is sent to the proper spark plug by the distributor, which is connected to the secondary terminal of the coil. As the system shown is designed for a six-cylinder engine, the distributor has six terminals in addition to the central terminal.

SPARK PLUGS

In the high-tension ignition system, the spark for igniting the fresh charge jumps a small gap between the electrodes of a device called a *spark plug*; on this account, the high-tension system of ignition is often referred to as the *jump-spark* system.

The almost universal form of spark plug consists of a central wire that passes through insulating material; the insulation is surrounded by a threaded bushing that screws into a hole in the engine cylinder. The central wire is thus insulated from the external bushing. The spark gap between the cen-

tral wire and the external bushing is formed in many ways; as a usual rule the gap varies from $\frac{1}{8}$ to $\frac{1}{4}$ in. For use in connection with magneto-electric generators and non-vibrator coils, it is generally recommended by the makers of such apparatus that the width of the spark gap be from $\frac{1}{8}$ to $\frac{1}{6}$ in.; these values correspond approximately to .4 mm. and .5 mm.; for dynamo-and-storage-battery ignition, a gap of approximately $\frac{1}{4}$ in. is usually recommended.

The outer bushing of the plug forms part of the frame-connected side of the high-tension circuit; only the central wire of the plug is insulated from the engine.

The material used for insulating the parts of the spark plug from each other is usually porcelain, mica, or steatite. The threaded bushing is made of steel, brass, or bronze.

There are three standard sizes of thread for spark plugs, known as the $\frac{1}{2}$ -in., the *metric*, and the *A. L. A. M.* or *S. A. E.* standard, the latter having been designed by the engineering branch of the Association of Licensed Automobile Manufacturers and later indorsed by the Society of Automobile Engineers.

The $\frac{1}{2}$ -in. standard spark plug is threaded with a $\frac{1}{2}$ -in. pipe thread, and hence is tapered; the standard metric spark plug has a straight thread 18 mm. in diameter and 1.5 mm. pitch. The *A. L. A. M.* standard spark plug has a straight thread $\frac{7}{8}$ in. in outside diameter, 18 threads per in.; length of threaded part from the end to the shoulder is $\frac{1}{2}$ in.; the hexagonal part receiving the wrench for screwing in the spark plug is either $\frac{7}{8}$ in. or $1\frac{1}{8}$ in. across flats; the thread is of the U. S. standard form, that is, flattened at the top and bottom an amount equal to one-eighth the pitch of the thread. As the *A. L. A. M.* as well as the metric standard spark plug has a straight thread, a tight joint between the plug and cylinder is made by a gasket, usually of the copper-asbestos type.

Adapter bushings, threaded outside with the $\frac{1}{2}$ -in. pipe thread, and inside with a thread to fit the metric standard spark plugs, are on the market, and thus permit metric spark plugs to be used in engines having the spark-plug hole tapped for $\frac{1}{2}$ -in. standard spark plugs. Adapter bushings can also be obtained which are threaded for metric plugs on the inside, and

have their outside threaded to fit holes tapped for A. L. A. M. standard spark plugs. The $\frac{1}{2}$ -in. standard spark plugs cannot be made to fit spark-plug holes tapped for A. L. A. M. plugs, it being impossible to make an adapter bushing for this purpose.

AUXILIARY SPARK GAP

A spark plug whose insulation has become somewhat defective can sometimes be made to perform its service by connecting in series with the gap at the spark plug a device known as an *auxiliary spark gap*. This device consists simply of two insulated terminals attached to the spark plug, or otherwise placed in the secondary circuit, with points separated by an adjustable gap, usually about $\frac{1}{16}$ in. in length.

MAGNETO-ELECTRIC GENERATORS

CLASSIFICATION

Most of the electric generators used directly for ignition in automobile work are synchronously driven and generate an alternating current. With rare exceptions, there is embodied in their construction a device for breaking the primary current, and a distributor for distributing the secondary current to the different cylinders; consequently, if the magneto delivers a low-tension current, it needs only one spark coil for a multi-cylinder engine. The only prominent exception is found in the magneto of the Ford car, which, while synchronously driven, discharges a high-frequency alternating current through a timer driven by the engine to individual spark coils of the vibrator type. Most of the electric generators employed only for ignition work use permanent magnets for field magnets; they are therefore called *magneto-electric generators*, or *magnetos* for short.

Magnetos are divided into two general classes, *low-tension* and *high-tension*. In jump-spark ignition work a low-tension magneto delivers a low-tension current to a separate induction coil; a high-tension magneto either has the induction coil carried inside the magneto or has a secondary winding directly over the primary winding of the armature, and thus delivers

a high-tension current without any outside apparatus. In other words, a high-tension magneto is self-contained.

Many magnetos are arranged for dual ignition, using for the battery ignition system the same spark plugs that are used for the magneto ignition system. In that case the contact breaker of the magneto, when the battery ignition system is used, serves to break the primary current of the battery, and the distributor of the magneto distributes the high-tension current coming from the spark coil of the battery system. Sometimes a separate contact breaker is provided for the battery current.

In double ignition systems, as a general rule, the magneto-ignition system and the battery ignition system are entirely independent of each other, each system having its own spark plugs. The battery system may have individual vibrator or non-vibrator spark coils and its own engine-driven timer, or it may have a single spark coil of either the vibrator or non-vibrator type, and an engine-driven timer and distributor.

Multipoint ignition, that is, two spark plugs for each cylinder sparked simultaneously, is used to some extent. One way of accomplishing this is to fit the magneto with two distributors, each serving its own set of spark plugs. Two separate magnetos also have been and are used for this purpose, and if an additional, independent battery ignition system is used (which may form part of a dual system with one of the two magnetos), the engine will have three ignition systems, or a *triple ignition system*, as it is usually called. The advantage of multipoint ignition is that, with the points of ignition properly located, the time required for the complete inflammation of the mixture will be reduced.

When two independent ignition systems are used, one employing a magneto and the other a battery, the switch is sometimes so arranged that both systems can be used simultaneously.

Still another way of obtaining multipoint ignition, without changing the dynamo-and-storage-battery or the magneto ignition system, is by the use of so-called *series spark plugs*, there being one series spark plug in series with an ordinary spark plug in each cylinder. Series spark plugs differ from the

ordinary spark plugs in that both electrodes are insulated from the shell of the plugs; they are made by several concerns and are regularly on the market.

ELEMENTARY MAGNETO GENERATOR

An elementary form of alternating-current magneto-electric generator is illustrated in Fig. 1, which shows the armature core and pole pieces *N* and *S* of permanent magnets to which they are attached, and also a coil consisting of two active conductors *c* and *d* connected in series and having their free ends joined to two metal collector rings, or slip rings, *g* and *h*. As the armature core and the coil rotate, conductor *c* is passing under a north pole at the same time that conductor *d* is passing under a south pole, so that the E. M. F.'s generated in the two conductors, though opposite in direction with reference to the poles, are the same in direction with reference to the coil; hence, the E. M. F. between the collector rings is the sum of the forces generated in conductors *c* and *d*. Stationary copper strips *e* and *f*, called brushes, rub on the collector rings as they rotate with the armature, and an alternating current flows through the brushes and the external circuit *R*. The arrows along the conductors and the external circuit show the direction of the current at the instant represented. When the armature has rotated until the conductors *c* and *d* have exchanged positions, the direction of the current through the coil and the external circuit will be reversed.

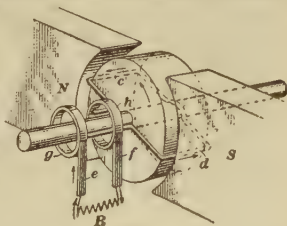


FIG. 1

Instead of having but a single turn of wire, as in the loop shown in Fig. 1, a coil consisting of a great number of turns is used in practice, so that the E. M. F. generated in each turn may be added to that of all the others. Furthermore, in order that the greatest possible number of lines of force may flow between the magnet poles and through the coil, the coil is

wound on a core of soft iron adapted to fit closely between curved polar extensions, or pole pieces, of iron secured to the poles of the permanent magnets.

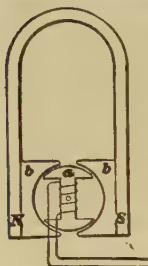


FIG. 2

ARMATURE CORE AND FIELD MAGNETS

The magneto-electric generators usually consist of an armature core *a*, Fig. 2, having wound thereon a single coil of many turns of fine insulated wire, and arranged to rotate between the poles *b* of one or more U-shaped permanent magnets *N S*. The armature core is usually made with a cross-section resembling the letter **H**, the best ones being laminated. One end of the armature coil is usually connected to the armature shaft, and the other to an insulated pin

or ring. The collecting brushes rub against the shaft and the insulated pin or ring.

Fig. 3 illustrates a typical armature having an **H** section. One end of the armature winding *a* is connected to the insulated slip ring *g*, and the other end is connected to the armature core and spindle. The deep flange *c* and the shallow flange *d* prevent oil from the bearings from reaching the winding; the flange *c* also insulates the slip ring *b* from the ball bearing. The end pieces *e* and *f* are made of some non-magnetic material, generally brass, bronze, or aluminum alloy. The spindle is usually made of steel. The non-magnetic heads magnetic-

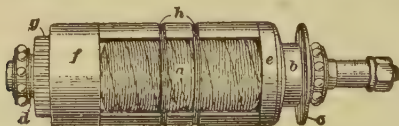


FIG. 3

ally insulate the spindles from the armature core. The circumferential bands *h* around the armature hold the wires of

the coil in place, so that they will not fly outwards when the armature is rotating. They also are made of non-magnetic material. The spur gear *g* drives the distributor of the magneto.

The form of armature here shown is often called a *shuttle-wound armature*. While most magnetos employ a shuttle-wound rotating armature, there are other designs in use. In some magnetos the armature winding is stationary and the armature core revolves; in others the armature core and windings are stationary and a perforated magnetic screen revolves between the armature core and the pole pieces; in another type a multiplicity of horse-shoe magnets are attached to the flywheel and revolve past stationary coils.

Fig. 4 shows the magnets, or field, used with armatures of the form illustrated in Fig. 3. The field is made up of two or more magnets placed side by side. Each magnet is usually double, or compound, consisting of one magnet *a* fitted over another *b*. Iron or soft-steel pole pieces *c* bored to suit the armature are attached to the magnets. The magnets are fastened firmly to a non-magnetic plate *d* that forms the base of the generator.

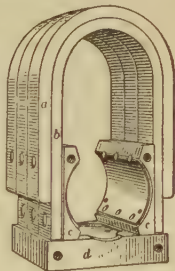


FIG. 4

SPARK TIME VARIATION

The power generated in the cylinder of an automobile engine depends, to a large extent, on the time at which the primary circuit is interrupted, because it is then that the spark is formed and the combustible mixture ignited. In order to obtain the very best results from each explosion, the spark should occur at the most advantageous point in the compression stroke of the engine. This point varies with different engines and depends on the size of the combustion chamber, the degree of compression in the cylinder, and the speed of rotation of the engine.

The time at which the spark should occur depends on the size of the combustion chamber, because with a small cylinder less time is required to completely ignite the mixture, and hence the spark need not occur any appreciable length of time before the crank reaches its upper or outer dead center; with a larger cylinder and combustion chamber, a longer time is required for complete ignition, hence the spark must occur earlier. The time of ignition depends on the degree of compression in the cylinder, because, if the gas or combustible mixture is very dense, it will burn more rapidly than if it were not compressed to so high a degree, so that with high compression in a cylinder the spark need not occur as early as with low compression. The speed of the engine influences the time of ignition because with a high piston speed there is less time for the mixture to burn than with a low piston speed, and hence the spark should be advanced farther, that is, ignition must occur earlier for a higher engine speed than for a low engine speed.

METHODS OF SPARK TIME CONTROL

If an internal-combustion engine runs at a constant speed, the spark should always occur at the same point on the compression stroke, for the three factors affecting the timing of the spark remain constant all the time the engine is running. Hence, with such an engine there is no necessity of providing means for varying the timing of the spark, and none are provided; or, in other words, a *fixed spark* is used. With an automobile internal-combustion engine, however, the speed of the engine varies necessarily between wide limits; hence, if a fixed spark is used, it will produce best results at the one engine speed for which it was fixed and will produce inferior results at other engine speeds. In spite of this fact, a fixed spark is used in some automobiles for the sake of simplifying the control of the machine.

If it is desired to be able to obtain the best possible burning of the fresh charge at all engine speeds, means must be provided for varying the time at which the primary circuit is either closed or broken, and while the engine and the automobile are in motion. An ignition system in which the timing of the spark

can be varied by hand has a *variable*, or *hand*, *spark control*; if the timing is varied automatically by a change in the engine speed, the system has an *automatic spark control*, or a *governor spark control*.

HAND SPARK CONTROL

The most natural, and consequently the most common, method of controlling the spark advance is by hand-operated means. On the majority of automobiles, the timer or the interrupter is operated through rods and levers from a hand lever on the steering post. Usually a rod extends downwards through the center of the steering column, although in some cases this rod is placed alongside this column and is connected by other rods and levers to the movable part of the timer or of the interrupter. The upper end of the rod in or alongside the steering column is turned by a hand lever so that when the lever is moved in one direction it rotates the timer or the interrupter and causes the spark to occur earlier, while if it is moved in the other direction it causes the spark to occur later.

In many cases it is impossible to tell at the first glance which is the spark lever and which is the throttle lever, neither one being marked to indicate its purpose. In other cases, either the two levers or the quadrants over which the levers slide, are plainly marked to indicate their purpose, the spark lever usually being marked **S** and the throttle lever **T**.

Where one is not familiar with a car, the spark lever can be located by lifting the hood from the engine and noting whether the rod running to the timer or the interrupter, or that leading to the carbureter, is moved when one of the levers is pushed forwards or backwards. The spark lever is the one that is connected to the timer or interrupter. Also, the direction in which the hand lever must be moved to advance or retard the spark is not the same on all automobiles, so that it must sometimes be ascertained by experiment or from the manufacturer's book of instructions.

Where an engine is fitted with two independent ignition systems, as a battery system with an induction coil and a timer, and a magneto system, the circuit-breaking mechanism of the magneto is usually interconnected with the timer of the battery system, or the circuit-breaking mechanism of the mag-

neto and the timer of the battery system are connected separately to the same spark lever. The circuit-breaker and the battery-system timer are so adjusted in reference to each other that the spark will occur in the engine cylinder at the same point of the piston stroke, irrespective of whether the battery ignition system or the magneto ignition is used. This means that the position of the spark lever for any given point of ignition is the same for both ignition systems.

GOVERNOR SPARK CONTROL

In order to do away with the necessity for a spark-advance hand lever on the steering wheel, and thus simplify the control of the engine and yet obtain the spark at the proper time, an automatic governor control is used in some ignition systems. When this control is used, the steering-wheel hand spark lever and all the connections to the timer or interrupter are sometimes done away with, so that the driver need only manipulate the throttle lever; the spark advance is then taken care of by the governor.

Automatic control of the spark advance is based on the fact that a weight revolved around an axis not passing through its center of gravity moves away from this axis unless restrained, the force causing this outward motion being known as *centrifugal force*. In practice, two or more equal weights are employed, which are so distributed as to be in balance in order that harmful vibrations may not be set up when the weights are revolving at high speed. The weights of the governor are either incorporated in the ignition apparatus itself, or they are placed in a coupling between the drive shaft and the ignition apparatus; they are arranged so that when the speed of the engine is increased they fly outwards and by the proper mechanism cause the spark to occur earlier. As the engine, and consequently the governor, slows down, the weights move in again and thus retard the spark. By the use of the governor control, the spark is advanced when the engine speeds up and retarded when it slows down, without any attention from the driver. Examples of automatic governor control are the *Eisemann automatic advance*, the *Delco governor control* (made in various ways), the *Atwater Kent governor control*, the *Remy*

governor control, and the *multiple-ball coupling control*, which is used on the Simms magneto and the Herz-Ruthardt magneto.

In practically all modern cars with automatic spark control, this is supplemented by hand control.

SPARK INTENSITY

Factors Affecting Spark Intensity.—When a battery ignition system is used, the primary current has the same strength regardless of the timing of the spark in relation to the stroke of the engine piston, hence a spark of the same intensity is obtained throughout the whole spark range from fully retarded to fully advanced; the intensity of the spark is not affected in any way by the speed of the engine, for the source of the current is independent of the engine. It is assumed here that the battery gives a current of sufficient strength to produce a spark. When either direct-current dynamos or magnetos are used for ignition, they are driven by the engine; therefore, generally speaking, the strength of the primary current as well as the intensity of the spark varies with the speed of the engine, being least at low engine speeds and highest at high engine speeds. There is an exception, however, in the case of non-synchronous friction-driven dynamos with a centrifugal-governor control; in this the governor prevents the armature exceeding a certain maximum speed, and consequently there is a maximum limit to the spark intensity, which limit is usually somewhat below that obtainable at the highest engine speed if the armature were positively driven.

All direct-current dynamos used for ignition and at least one form of synchronous alternating-current magneto, which is constructed with a large number of magnets, merely take the place of the battery as a source of current, and are used in conjunction with a timer, or with a distributor and timer, depending on whether there is an induction coil for each cylinder or a single induction coil for all the cylinders. In such dynamos and such a magneto, the intensity of the primary current is practically constant throughout the whole revolution of the dynamo or magneto armature; consequently, a spark of practically uniform intensity is obtained through the

whole spark range, the spark intensity varying only with the armature speed.

Synchronous magnetos with shuttle armature usually generate an alternating current; they have a primary circuit-breaker, that is, an interrupter, and a high-tension distributor incorporated in their construction. With all such magnetos, regardless of whether they generate the high-tension current directly in the magneto or in a separate induction coil, the spark intensity varies with the armature speed; the spark intensity through the spark range may be uniform, practically uniform, or vary between wide limits at a given armature speed, depending on the construction of the magneto.

Many synchronous magnetos with shuttle armature are built for dual ignition, the second ignition system employing current from a battery, using either the same or a separate circuit-breaker operated by the rotation of the armature for breaking the battery current, an induction coil for the secondary current of the battery system, and employing the regular magneto distributor for distributing the high-tension current when the battery system is in use. With such magnetos, the spark intensity, when the battery system is in use, is uniform throughout the whole range and is independent of the magneto armature speed. When the magneto system is in use, the spark intensity varies with the armature speed and may or may not vary through the spark range.

Influence of Spark Intensity on Starting Engine.—With a battery system, the engine can be cranked with the spark fully retarded so as to prevent a back fire, and the cranking can be done at a very low speed, because the spark intensity is independent of the engine speed. When the ignition is furnished by a magneto giving the same, or practically the same, spark intensity through the whole spark range, the engine can be cranked with the spark fully retarded. As the strength of the secondary current varies with the armature speed, the engine will have to be cranked quite fast in most cases in order to get a sufficient current strength to have the current jump the gap at the spark plug. In fact, in many cases it may be necessary to turn the engine crank-shaft over several revolutions as fast as it can be done by hand in order

to get a sufficiently high armature speed to produce sparks at the spark plugs. When the ignition is furnished by a synchronous magneto giving a much weaker current when the spark is retarded than when fully advanced, the engine can rarely be started on the magneto with the spark retarded, as it cannot be cranked fast enough to get up an armature speed sufficiently high to give a spark at the spark plugs. It will usually be necessary to advance the spark lever to about the middle of the spark range, and sometimes even more, with the attendant risk of a back fire. As magnetos of this type are almost invariably used in connection with dual or with double ignition systems, it is the usual practice to employ the battery system for starting the engine and change over to the magneto system after the engine has been started. With some magnetos of this type it is necessary to change over to the battery system when the engine is running slowly driving the car on high gear, the armature speed being then insufficient to produce a spark.

Method Giving Spark Variable Over Magneto Spark Range.

In many cases the advance and retarding of the spark is obtained by rotating either the interrupter lever or the cam, depending on which part is fixed to the armature shaft, in relation to both the armature and field magnets. For instance, when the interrupter lever or mechanism is fitted to the end of the armature shaft and is turned by it, the cam is arranged so that it can be rotated backwards and forwards. When it is moved in the direction of rotation of the armature, the time at which the primary circuit is broken is made later and the spark is retarded. If it is moved in the opposite direction the spark is advanced. Where the cam is fixed to the end of the armature shaft, the advance and retarding are accomplished by rotating the interrupter lever. When this lever is moved in the direction of rotation of the armature, the time of interruption of the current is made later and the spark retarded. When it is moved in the opposite direction, the spark is advanced.

With a magneto having two pole pieces and the usual form of shuttle armature, irrespective of whether the magneto is of the low-tension or the high-tension type, the maximum E. M. F.

is produced in the primary circuit at two diametrically opposite points in the revolution of the armature, so that the best spark is obtained at the spark plug when the primary circuit is broken at these points. Magnetos are usually set so that the maximum spark is obtained when in the advance position, for that is the position most in use. But, with a magneto in which the primary circuit-breaking mechanism rotates in relation to both the armature and field magnets, the spark will be weaker as it is retarded, for the break in the primary circuit will not occur when the current is at the point of maximum intensity. On this account, such a magneto will not produce as good a spark when in the retard position as when in the advance position with the speed of the armature the same.

Methods Giving Spark Uniform Over Magneto Spark Range.—Many methods have been devised for use in connection with synchronous magneto ignition systems whereby it is possible to obtain a spark of the same intensity over the entire range of spark control from full advance to full retard, the armature speed being the same. Among these methods the most important are the following:

1. By rocking the field magnets, keeping the one part of the interrupter mechanism fixed in relation to the field magnets and all the other parts fixed to the armature. Either the interrupter lever or its equivalent, or the interrupter cam may be fixed in relation to the field magnets.

2. By making use of a coupling in the armature shaft by means of which the armature may be rotated in relation to the engine. Either the interrupting mechanism is rotated with the armature and the cam is held stationary in relation to the field magnets, or the cam is rotated with the armature and the interrupting mechanism is held stationary in relation to the field magnets.

3. By making use of a movable magnetic screen which is located between the armature and field magnets and to which one part of the interrupting mechanism is attached.

4. By the use of extended or specially shaped pole pieces.

EXAMPLES OF MAGNETOS

The Eisemann magneto shown in Fig. 5 delivers a high-tension current direct to the spark plugs, without the use of a separate induction coil. The magnetic field is created by two permanent horseshoe magnets that fit accurately over the pole pieces between which the armature rotates. The pole pieces are so shaped that a hot spark is obtained at low engine speed and a very wide range of timing the spark is made possible.

The armature is known as the *shuttle type*, as it is wound in the same manner as a shuttle. The spark is advanced or retarded by rocking the breaker box *a*, Fig. 5, by means of the timing lever *b*.

The wiring diagram of the Eisemann magnet is shown in Fig. 6. The terminal marked *MA* on the breaker-box cover is connected to the upper switch connection *b* by a low-tension cable, and the lower switch connection *c* is connected by another cable to some metal part of the engine, forming a *ground*. The high-tension terminals are connected to the spark

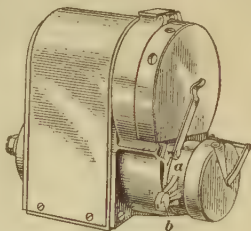


FIG. 5

plugs in the proper order for the engine to fire. If in doubt as to the correct firing order, have someone crank the engine slowly by hand and watch the opening of the inlet valves. The cylinders fire in the same order that the inlet valves open.

When the switch is in the running position, which is usually when the switch key is turned a quarter turn in either direction, the primary circuit from terminal *MA* to the ground is broken. With the switch in the off position, the ground connection is closed, and the magneto armature current is grounded. No spark is then produced at the spark plugs. A *safety gap* is provided to give an outlet for the high-tension current in case a spark plug cable becomes disconnected. The high-tension current will jump across the safety gap and thus protect the

secondary winding and other high-tension insulations. It serves the same purpose as the safety valve in a steam boiler, and consists of two pointed contacts placed inside of the gear housing at a certain specified distance from the collector ring.

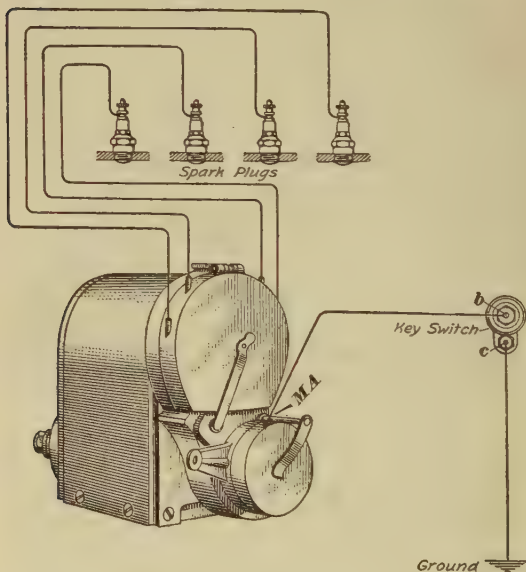


FIG. 6

Timing the Magneto.—The first step in timing any magneto after it has been fastened to its seat is to adjust the control rod or rods so that the spark-control lever, in moving through its whole range, will also move the magneto breaker mechanism

through its full retard and advance ranges. It is necessary, also, that the timing be such that with the spark fully retarded, the contact points will open when the piston in the cylinder being timed is on its compression dead center.

In timing the Eisemann G-4 magneto, the engine is turned by hand until the piston of No. 1 cylinder is on dead center at the top of its compression stroke. The distributor plate, or head, is then removed and the armature shaft is turned until the setting mark 1R on the distributor disk is in line with the small projecting screw in the upper part of the distributor cover. With the armature in this position, the platinum contacts are just at the point of opening, and the metal insert of the distributor rotating disk is in connection with the segment leading to No. 1 cylinder. The magneto is now coupled to the engine driving shaft without disturbing the position of the armature shaft, and the cables connected to their respective spark plugs.

With some magnetos it is not necessary to remove the distributor head in timing, as a small window is cut into the head which exposes to view figures on the distributor disk. These figures show with what terminal the distributor brush or rotor makes contact. All makers of magnetos issue instructions for timing each model made by them, but in case such instructions are unavailable, the following general instructions may be followed.

With the spark fully retarded, the piston in cylinder No. 1 is placed on compression dead center, and, with the distributor head removed, the armature shaft is rotated until the distributor brush is in contact with the magneto terminal leading to cylinder No. 1. If this terminal is in the distributor head, the distributor housing should be marked so as to indicate its position. The armature is then turned very slowly until the contact points are at the point of opening, and the armature is then coupled to the magneto driving shaft of the engine.

A magneto cannot be run in both directions, hence in ordering state the correct rotation as seen from the driving end of the magneto. If no definite information is given about the direction, it is assumed that it is intended to be run clockwise, and such a magneto will be sent.

In magnetos in which no numbers are marked on the dis-

tributor rotor or on the distributor-head terminals, any terminal may be considered as No. 1, and be connected to cylinder 1, the usual practice being to assign the number 1 to the cylinder nearest the front end of the car. It must be remembered that the distributor rotor distributes the high-tension current to the distributor terminals in a direction opposite to that in which the armature rotates.

A well-known example of the high-frequency alternating-current low-tension magneto is that used on the Ford Model T automobile. Fig. 7 (a) shows this magneto assembled in the

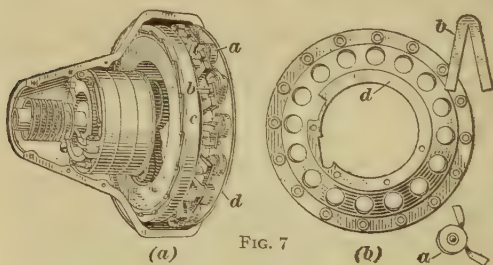


FIG. 7

case with part of the planetary transmission system. The magneto consists essentially of a stationary armature containing sixteen spool-shaped coils *a* attached to a spider that, in turn, is attached to the cylinder casting, and a set of the same number of permanent horseshoe magnets *b* fixed to the flywheel and rotating with it. The magneto is therefore direct-connected to the engine and is located at the rear end of the crank-case.

One of the armature coils is shown in detail at *a*, view (b). Each coil has two windings of copper ribbon wire, one winding being clockwise, and the other counter-clockwise. The coils, which are arranged at equal intervals around the armature plate *d*, are connected in series with each other, the two terminals being brought out at the top of the casing. One of the

terminals is connected by means of a spring connection to a binding post on top of the magneto and the other terminal is grounded on the armature plate. At *b*, view (b), is illustrated one of the horseshoe magnets, sixteen of which are spaced around the flywheel *c*, as shown in view (a). The magnets are set with the closed ends next to the center of the flywheel and with the poles extending outwards and opposite the coils. In this arrangement, two north poles are placed together and two south poles are placed next to each other. The magnets revolve with the flywheel and at a distance of $\frac{1}{4}$ in. from the stationary coils, so that a magnetic field is set up about the coils and a current is induced in them. The current generated in the armature coils passes, by way of the binding post, through the induction coils and back through the engine frame and magneto frame to the grounded terminal on the armature plate, thus completing the circuit. As the magnets move through a large circle, they have a high peripheral speed in relation to the rotary speed of the engine. On account of this, a good spark may be formed by hand-cranking, for the magnets pass the coils at a comparatively high rate of speed even when the engine is turned over slowly.

In the Ford car using the magneto just explained, the coil box is located on the side of the dash next to the seat. It contains four induction coils with individual vibrators, there being one coil for each cylinder. Low-tension current is taken from the magneto at a binding post on top of the transmission cover and passes through a wire to a primary terminal common to all the induction coils. It then passes through the primary winding of the coil, which, at that instant, is connected in the circuit by the timer, through the proper wire to the contact piece of the timer, and then back to the magneto by way of the timer rotor and engine frame. For instance, assume that the rotor of the timer is in contact with contact piece 1. The primary current then passes through the primary winding of coil 1 (the one at the extreme right of the car), through the proper connection to the contact piece 1 of the timer, and back to the magneto by way of the ground.

While the current is passing through this path, the vibrator of coil 1 is rapidly opening and closing the primary circuit, so

that a current of high tension is induced in the secondary winding of that coil. This current passes through the high-tension cable to the spark plug of cylinder 1 and then back to the secondary winding of the coil by way of the engine cylinders and frame and rotor of the timer, completing the circuit through part of the primary circuit, as is the case in three terminal coil systems. The timer connections in this system are such that the order of firing is 1-2-4-3.

The Ford magneto ignition system, although classed as a single magneto system, is so arranged that it can be readily changed into a dual system by connecting up a battery so that it can be used to supply current in place of the magneto. The induction coils are provided with a binding post for connecting one terminal of the battery into the system, the second battery terminal being grounded to the frame. The connections to the switch regularly furnished on the coil box are such that, with a battery connected up in this manner, the regular switch may be used for cutting out the magneto and connecting the battery in the circuit without any other change being made in the system. When the battery is used for ignition in Ford cars, the battery current is independent of the magneto, but it passes through the same timer and induction coils as the magneto current.

The timer regularly furnished in the Ford Model T car is shown in Fig. 8 with its cover removed. The brass housing *a* is mounted on the forward end of the crank-case in such a manner that it can be rocked back and forth to advance and retard the spark, connection from the arm *b* of the timer housing being made to the spark-advance lever on the steering post. The housing *a* is confined longitudinally by the timer rotor *c*, which is pinned to the cam-shaft, and a shoulder on the bearing on which it can rock. A ring *d* made of insulating material is placed inside the housing *a* and has embedded in it four steel contact pieces *e*, each of which is provided with a terminal and knurled nut *f* for making a wire connection to its own induction coil. The timer rotor *c* has an arm *g* to which a bell-crank *h* is pivoted, which at its one end carries a large steel roller *i*; a helical spring *j* is attached to the other end of the bell-crank *h* and to a second arm *k* of the timer rotor. The spring *j* holds the roller in contact with the inside of the ring *d*.

The roller *i* is not insulated in any way from the engine, or, in other words, it is grounded; the segments *e*, however, together with their terminals, are completely insulated from the timer housing. Every time the roller *i* touches a segment *e*, the primary ignition circuit through one of the induction coils is closed, and as these coils are of the vibrator type, a shower of sparks is produced at a spark plug until the roller *i* rolls off the segment *e* with which it was in contact.

A removable brass cap or cover excludes dirt, and gives access to the inside of the timer.

The *Bosch high-tension magneto* belongs to the class employing a shuttle-wound rotating armature, with the secondary winding wound directly over the primary armature winding. An old model Bosch magneto used a double-wound stationary armature of the shuttle type. The Bosch mag-

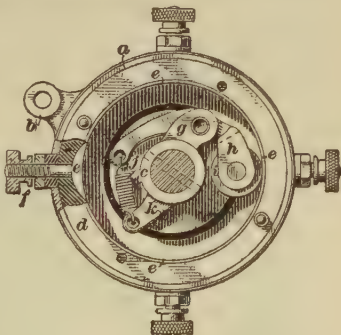


FIG. 8

netos are made for single and for dual ignition, and also for multi-spark ignition, the models used for single ignition being used without change for double ignition systems. The earlier models of the Bosch magneto were constructed so that the production of the spark in the fully retarded position required a much higher engine speed than in the fully advanced position; the latest models, through using extended pole pieces, are claimed to produce a spark at a lower engine speed in the fully retarded than in the fully advanced position.

A longitudinal section and an end view of a Bosch magneto, Type DU, Model 5, are given in Fig. 9. The one end of the primary winding is grounded to the armature core, and the

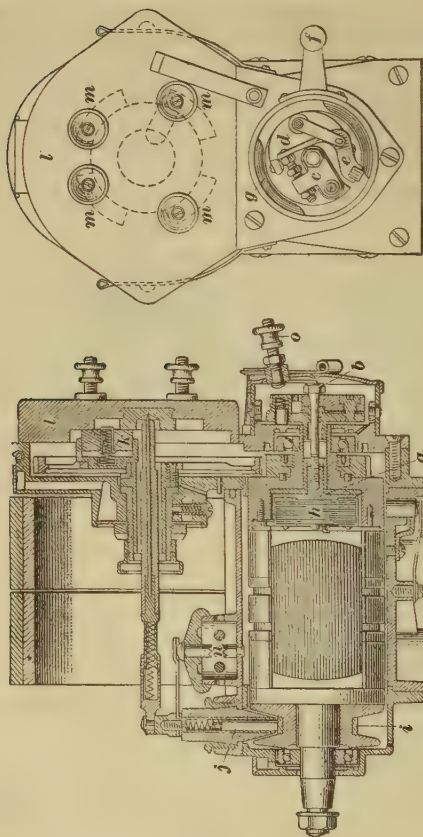


FIG. 9

second end is connected to the brass disk *a*. A fastening screw *b* passes through the center of the disk *a*; it holds the interrupter in place and also conducts the primary current to the interrupter contact block *c*. The screw *b* and the block *c* are insulated from the interrupter disk *d*, which is electrically connected to the armature core. The interrupter contact block *c* carries a platinum contact screw fitted with locknuts. The interrupter lever *e* is in the form of a bell-crank; it carries on one end a platinum contact screw contacting with the one in the block *c* and is held in contact by a spring. The interrupter lever is electrically connected to the armature core and hence to one end of the primary winding, which is thus short-circuited as long as the platinum screws of the contact block and interrupter lever are in contact. The interrupter housing *f* can be rotated to advance or retard the spark; it carries two steel cams that, through coming in contact with the one end of the interrupter lever *e*, break the contact between the screws of the interrupter lever and contact block *c*, thereby suddenly breaking the primary circuit. A condenser *h* is electrically connected in a shunt across the two contacts of the interrupter mechanism.

The secondary winding is placed directly over the primary armature winding, one end of the secondary winding being connected to the live end of the primary winding, and the second end to the slip ring *i*. A carbon brush *j* conducts the high-tension current to the carbon brush *k* of the distributor rotor. The distributor disk *l* is stationary and has embedded in it four metal segments *m* (for a four-cylinder engine) that connect electrically with terminals to which the spark-plug cables are attached. A safety spark gap *n* is placed in the high-tension circuit.

The Bosch magneto may be disconnected from the ignition by temporarily grounding the primary circuit by means of a simple switch. An insulated wire is led from the terminal *o* to one switch pole; the second switch pole is grounded. Closing the switch grounds the primary circuit and thus stops ignition.

Some Bosch high-tension magnetos have been equipped with a device for advancing and retarding the armature in respect to the engine, keeping the interrupter cams stationary in respect

to the pole pieces, the armature-advancing device being connected to the spark lever on the steering wheel. With this construction, the spark intensity is uniform over the whole spark range, as the primary circuit is always broken when the current has its maximum intensity.

The Bosch single ignition high-tension magneto, Type NU4, built for a four-cylinder engine, differs from other high-tension magnetos in that its distributor rotor is attached directly to the armature shaft and turns at the same speed. The circuit-breaker is arranged to break the primary current twice during each revolution of the armature, which means that high-tension current is sent twice during each revolution to the distributor. But, the distributor has four brushes electrically connected to four terminals leading to spark plugs, and the rotor has two segments 180° apart on which these brushes bear, so that two opposite brushes receive high-tension

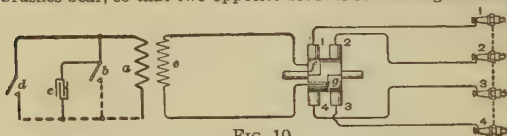


FIG. 10

current simultaneously; therefore, the high-tension circuit always includes two of the four spark plugs, which two plugs spark simultaneously. Consequently, there are eight sparks during every two revolutions of the engine crank-shaft, of which four are effective in firing the compressed fresh charge in the cylinders and four are non-effective.

The Bosch magneto, Type NU4, differs from other high-tension magnetos in that the secondary winding of the armature is not grounded. The electrical connections are indicated in the electric-circuit diagram in Fig. 10, in which *a* represents the primary winding of the armature, *b* the circuit-breaker, *c* the condenser, and *d* the ignition switch, which, when closed, forms a short circuit for the primary circuit, around the circuit-breaker, and thereby stops ignition. The one end of the secondary, or high-tension, armature winding *e* is connected to the segment *f* of the distributor rotor on the armature shaft, and the other end

is connected to the segment *g* on the same rotor, the two segments being insulated. The four brushes resting on the distributor rotor are marked 1, 2, 3, 4 in the illustration, and the four spark plugs are marked in accordance with the cylinder to which they are applied; the high-tension cables to the spark plugs are in this case connected to the brushes to fire the engine 1, 2, 4, 3, but can be connected to fire the engine 1, 3, 4, 2.

With the brush 1 on the segment *f* and the brush 3 on the segment *g*, and cylinder 1 on its compression stroke, the breaking of the primary circuit by the circuit-breaker induces a high-tension current, which passes from the winding *e* through the segment *f*, through brush 1 to spark plug 1, through ground to spark plug 4, through brush 3 and segment *g* back to the secondary winding; the spark at spark plug 4 is ineffective, however, as cylinder 4 is making the exhaust stroke. No spark can occur at spark plugs 2 and 3, because the high-tension circuit through these plugs is open. When the distributor rotor, which turns at crank-shaft speed, has turned 180° from the position shown, the high-tension circuit through plugs 1 and 4 is open, and that through plugs 2 and 3 is closed; consequently, upon opening the primary circuit, the spark plugs 2 and 3 spark, cylinder 2 being fired and cylinder 3 being near the end of its exhaust stroke. As the rotor turns another 180°, spark plugs 1 and 4 spark again, but as cylinder 4 is on its compression stroke, the charge in cylinder 4 is fired and the spark in cylinder 1 is ineffective, because it is making its exhaust stroke. Another 180° turning of the armature causes the plugs 2 and 3 to spark again, but this time cylinder 3 is on its compression stroke and cylinder 2 on its exhaust stroke, so that the charge in cylinder 3 is fired and the spark in cylinder 2 is ineffective.

If the firing order is 1, 3, 4, 2, distributor brush 1 is connected to spark plug 1, brush 2 to spark plug 3, brush 3 to spark plug 4, and brush 4 to spark plug 2.

The principle on which the *Dixie high-tension magneto* operates is entirely different from that of other high-tension magnetos, in that the armature has no wire windings and in the actual machine it forms a rotating extension of the poles of the magnets; the pole extensions of the armature rotate in a stationary magnetic-field structure which carries a small

primary and secondary winding. The general principle of operation is the sending of the magnetic flux alternately in opposite directions through the stationary magnetic-field structure, thereby inducing an alternating current in the primary winding, which, when interrupted suddenly at its time of maximum intensity, induces a high-tension current in the secondary winding, which is conveyed to the distributor and thence to the spark plugs.

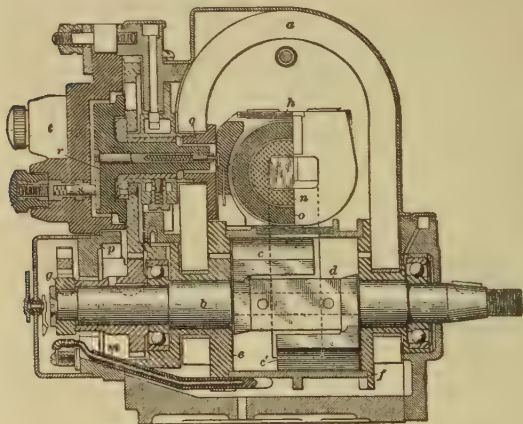


FIG. 11

The Dixie magneto is made for 4-, 6-, 8-, and 12-cylinder engines, the principle of operation being the same in each case, although the construction naturally differs.

A cross-sectional view of the 4-cylinder Dixie magneto is shown in Fig. 11. There are two horseshoe magnets, of which only one, marked *a*, can be seen in this view. The armature shaft *b* carries two pole extension pieces *c*, *c'* of magnetic material, that are separated by a non-magnetic distance piece *d*; these pole extensions are 180° apart, and each extends around

about 90° of the circumference. A separate view of the complete armature removed from the magneto is shown in Fig. 12 (a), where the pole extensions c, c' , the distance piece d , and the two magnets a can be clearly seen. Between the pole extensions c, c' , Figs. 11 and 12 (a), of the armature and the poles of the magnets, are interposed the front and rear housings e, f , which are made of magnetic material and carry the ball bearings on which the armature turns. Owing to the con-

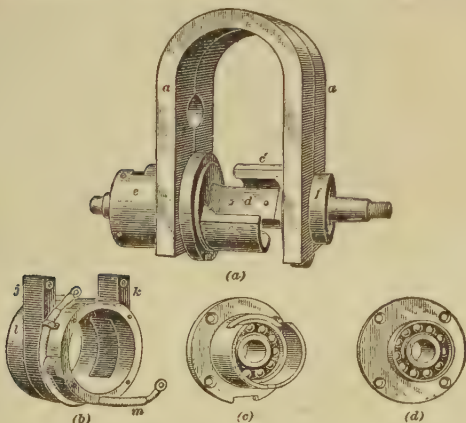


FIG. 12

struction, the pole extension c at all times has the same polarity as the pole of the magnets in contact with the front housing e , and the pole extension c' has the opposite polarity; that is, if the pole extension c is a north pole, the pole extension c' is a south pole. The cam which operates the circuit-breaker is shown in Fig. 11 at g , and the condenser, which is shunted across the circuit-breaker contacts, is shown at h . The laminated field structure, consisting of two soft-iron pole pieces and a crosspiece, or core, i on top, is mounted on the two

housings *e*, *f*; the field structure removed from the magneto is shown in Fig. 12 (*b*), where the two laminated iron pole pieces can be seen at *j* and *k*, and where the core is removed. The front housing shown in Fig. 12 (*c*), as well as the rear housing shown in (*d*), are fastened each by four screws to the barrel-shaped part *l* of the field structure, which is made of non-magnetic metal and has the pole pieces *j*, *k* inserted in it. The wire *m*, shown in both Fig. 11 and Fig. 12 (*b*), connects one end of the primary winding *n*, Fig. 11, to the stationary contact of the circuit-breaker; the other end of the primary winding, as well as the one end of the secondary winding *o*, is grounded. The core *i*, Fig. 11, on which the coil containing the primary winding *n* and secondary winding *o* is mounted, is fastened to the top of the pole pieces *j*, *k*, Fig. 12 (*b*). The housings *e* and *f* are not fastened in any way to the magnets, but are so mounted that they, as well as the pole pieces and coil containing the windings, can be rocked to some extent by rocking the circuit-breaker, which is carried by the circuit-breaker housing *p*, Fig. 11, fastened to the front housing *e*. As the circuit-breaker moves with the pole pieces, the primary current is interrupted at its point of maximum intensity regardless of the position the pole pieces or circuit-breaker are in; that is, the spark intensity is uniform over the whole spark range.

The second end of the high-tension winding *o*, Fig. 11, is connected to a crescent-shaped brass-plate contact that moves with the whole field structure, and against which bears a brush *q* that conveys the high-tension current to the distributor rotor segment *r*, which distributes it to carbon brushes at *s*, each of which is electrically connected to a spark-plug terminal of the distributor head *t*.

ELECTRIC STARTING AND LIGHTING

CLASSIFICATION AND ESSENTIAL PARTS

The electric starting, lighting, and ignition systems used in automobiles are divided into three general classes.

In a *three-unit system*, the motor, the generator, and the ignition apparatus are entirely separate structures. The ignition apparatus may be a single or dual magneto, or it may be a

timer-distributor apparatus drawing current from dry cells or the dynamo-and-storage-battery combination, or there may be two independent ignition systems.

There are two general divisions of the *two-unit systems*. In one division, the motor and the dynamo are combined into a single machine and the ignition apparatus forms a separate unit. In the other division, the motor forms one unit and the dynamo and ignition apparatus are combined into a second unit.

In automobile practice, the terms *dynamotor* and *motor-generator* are often used interchangeably to mean an electric machine that generates current when driven by the automobile engine, and that acts as a motor when current is supplied to it.

Dynamotors used in automobile work are divided into *single-commutator* and *double-commutator machines*; both classes have a single armature. Single-commutator machines have only one armature winding; double-commutator machines have two armature windings, each having its own commutator.

Some makers of automobile starting and lighting systems have assembled an electric motor and a separate electric generator in the same housing, each machine having its own field and armature and there being no fixed mechanical connection between the two machines; this combination is not a dynamotor or motor-generator, but forms part of a three-unit system.

In a *single-unit system* the motor and generator are in the form of a dynamotor, combined with which is a timer-distributor arranged to draw its current from the dynamo-and-storage-battery combination.

The essential parts of an electric starting system are a storage battery, a motor, a switch for the motor, the necessary wiring, and in certain cases some device for disconnecting the motor automatically from the engine as soon as this takes up its cycle of operation, that is, begins to run under its own power.

The essential parts of an electric lighting system are a storage battery, a generator which may be permanently connected to the engine, switches for turning on and off various combinations of the lights, the wiring, and means for regulating the output of the generator. Desirable accessories are an

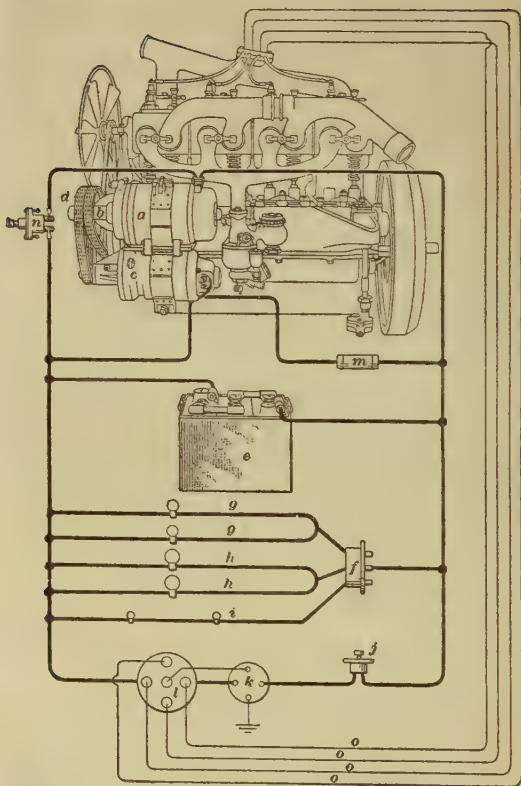


FIG. 1

automatic reverse-current switch, which prevents the battery discharging itself through the generator, and some form of indicator that shows whether the battery is charging or discharging.

When both an electric starting system and an electric lighting system are fitted to a car, as is now the usual rule, the same storage battery is used for supplying current to the electric motor and to the lights, and perhaps also to the ignition apparatus.

In order to show the relation of the different parts of the electric equipment of an automobile, Fig. 1 is presented. This illustration shows, partly in diagrammatic form, all the essential parts of a three-unit system, ignition in this case being effected by current from a dynamo-and-storage-battery circuit, a timer-distributor, and an induction coil. Fig. 1 does not represent any particular make of electric equipment, but has been prepared to show the salient features and relationship of the component parts of such equipment.

The engine is cranked by the starting motor *a*; an over-running clutch is fitted inside the sprocket wheel *b* so that the armature remains at rest while the engine is running under its own power. The electric generator *c* is driven from the engine by a driving sprocket *d* fastened to the side of the motor-drive sprocket in this particular case. The motor *a*, the generator *c*, the storage battery *e*, the lighting system, including the switch *f* and the lighting circuits *g*, *h*, and *i*, and the ignition system, consisting in this case of an ignition switch *j*, an induction coil *k*, and a timer-distributor *l*, are all connected in parallel.

A reverse-current switch *m* is placed between the generator and storage battery in such a position that while it prevents the flow of electricity from the storage battery to the generator at all times, it does not prevent electricity from flowing to the motor when the motor-starting switch *n* is closed, or to the lights when any of the buttons of the switch *f* are pressed in, or to the ignition system when the switch *j* is closed. A storage battery connected as here shown, that is, in parallel with its source of current supply and with the electric system or systems to which it delivers current, is said to be *floated on the line*.

The wires *o* convey the high-tension ignition current from the distributor to the spark plugs.

The manner in which the storage battery and the dynamotor, or an electric generator if this is separate from the motor, act in reference to each other and also to the electric lights, and to the ignition system if the current for this is drawn from the dynamo-and-storage-battery combination, is as follows: At low engine speeds, the voltage due to the generator is less at the battery terminals than that of the storage battery, and consequently current passes from the storage battery to the lights and ignition circuit. As the engine speed is increased, the voltage of the generator increases until it is somewhat higher at the battery terminals than that of the storage battery; consequently, current passes from the generator into the storage battery and also to the lights and to the ignition circuit.

If the electric system is equipped with an automatic reverse-current switch, this opens whenever the generator armature runs so slowly that the storage-battery voltage is enough higher than the generator voltage for the storage battery to furnish the current for the lights and ignition circuit. This reverse-current switch being in series with the electric generator, as shown in Fig. 1, prevents the storage battery from driving the generator as a motor at low engine speeds; it also prevents the battery discharging itself from being short-circuited through the generator armature while the engine is not running.

In some electric systems employing a dynamotor no reverse-current switch is used, and the dynamotor is permanently connected to the engine. In consequence, as long as the starting switch is closed, the dynamotor will act as a generator when its armature is driven fast enough. When the engine is slowed down very much, however, the battery voltage will exceed that of the dynamotor, and this will be driven as a motor, assisting the engine to drive the car and tending to prevent the engine from *stalling*. An engine equipped with a dynamotor arranged as just explained is called a *non-stallable engine*.

DYNAMOTOR CONNECTIONS TO ENGINE

When a motor-generator is so designed and installed that its armature makes the same number of revolutions per revolution of the engine crank-shaft when running as a motor

as when running as a generator, no overrunning clutch is needed in the driving connection between the dynamotor and the engine. This is not the case, however, if the revolutions of the armature per revolution of the crank-shaft are different when running as a generator than when running as a motor; in all such cases, two overrunning clutches must be fitted, unless the dynamotor when running as a generator is driven by some non-positive means, as by a belt for instance. Where an ignition apparatus is combined with a dynamotor that requires two overrunning clutches, the one overrunning clutch must be placed between the ignition apparatus and the armature of the dynamotor, in order that the ignition apparatus may always be properly timed in relation to the movement of the engine pistons.

OVERRUNNING CLUTCHES

An overrunning clutch permits motion to be transmitted only in one direction by its driving member, automatically releasing the connection between the two shafts coupled together by the clutch when the driven clutch member becomes the driving clutch member. This prevents the armature of an electric cranking motor from being driven by the engine when this is running at a speed at which it would rotate the armature faster than it runs when cranking the engine.

The overrunning clutches generally used in practice may be divided into roller clutches, jaw clutches, and ratchet-and-pawl clutches. The last-named type is divided into plain and automatic ratchet-and-pawl clutches. In any pawl-and-ratchet wheel mechanism, the sliding of the pawl over the ratchet teeth makes an extremely disagreeable noise; to prevent this noise, means must be provided for arresting the sliding of the pawl over the teeth. In a plain ratchet-and-pawl clutch, this is usually accomplished by permitting the ratchet wheel to rotate with the member carrying the pawl or pawls; in automatic ratchet-and-pawl clutches, the pawl or pawls are automatically lifted away from the teeth of the ratchet wheel when the engine is running under its own power. While other forms of overrunning clutches are in existence, their use is generally confined to some particular make of car.

STARTING TRANSMISSIONS

When an electric cranking motor or a dynamotor is connected to an engine by means of a sliding-gear starting transmission, which, as a general rule, drives to a gear cut in the face of the engine flywheel, some means are usually provided for insuring an easy meshing of the teeth of the sliding gears with the gear or gears that do not slide. It is readily seen that when the teeth of sliding gears are opposite the teeth of gears that do not slide the teeth clash against each other and the gears cannot be *meshed*, that is, caused to engage; in order that the gears may mesh, the teeth of one set of gears must be opposite the spaces between the teeth of the second set of gears.

One way by which an easy meshing of the gears is insured is to cause the motor- or dynamotor-armature shaft, which usually carries one of the gears that does not slide, to revolve slowly. This is accomplished in several ways, among which may be mentioned the use of a starting switch that places a resistance in series with the field winding of the electric motor, thereby permitting only a small current to pass through the motor. As soon as the gears are fully meshed, the switch cuts the resistance out of the circuit and the maximum current passes from the storage battery to the motor.

The means by which a sliding-gear starting transmission is meshed, thus connecting the starting motor to the engine, varies in different cars and in different systems. Among the most widely used means may be mentioned the use of a separate hand lever, a separate pedal, an interlock with the clutch pedal or the gear-shift lever, a purely electromagnetic operating device, and the use of an inertia clutch.

The *Eclipse-Bendix inertia clutch*, or automatic engagement device for coupling the cranking motor to the flywheel of the engine, is shown in perspective in Fig. 2 (a), and in an engaged position in (b); both views should be referred to in reading the description. In the particular design here shown and called the *outboard* type by the makers, because it requires a bearing at the extreme outer end of the armature shaft, the one end *a* of this shaft, has a right-handed multiple thread of coarse pitch cut on it. The bore of the driving pinion *b* is threaded to suit *a* and is a loose fit thereon; the driving pinion

has a weight *c* that causes it to assume the position shown in (a) when the armature is at rest. A nut *d*, the outside of which forms a journal running in the bearing *e*, serves as an abutment that locks the pinion *b* to the shaft *a* when the pinion has traveled into its engaged position. The armature shaft *c*

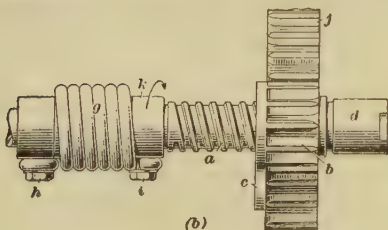
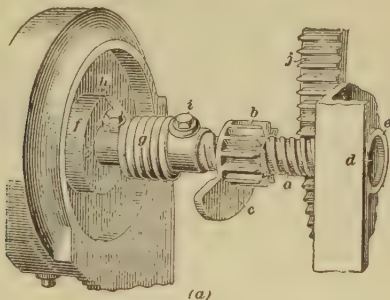


FIG. 2

is divided just outside the motor bearing *f*, the two halves being connected by a coupling *g* in the form of a helical spring; the one end of the spring coupling is anchored at *h* to one part of the armature shaft and at *i* to the other part.

When the cranking motor is at rest, the driving pinion *b*, Fig. 2, is out of engagement with the flywheel gear *j*, as shown

in (a). When the cranking motor is started, the pinion *b*, by reason of its inertia and its being loose on the shaft, lags behind the armature shaft rotating as shown by the arrow *k*, and consequently is moved toward the end of the shaft by the screw threads, into the position shown in (b), where it meshes with the teeth of the flywheel gear *j* and is forced to rotate with the armature shaft because it butts against the nut *d*. The flywheel being at rest and hence the engine offering considerable resistance to cranking, the cranking motor coils up the spring *g* until its tension is sufficient to start the flywheel from rest with a jerk; the engine is now being cranked. When the engine fires, the pinion *b* is driven faster in the same direction than the armature shaft, and therefore travels along the screw threads out of mesh with the gear *j*, thus dispensing with an overrunning clutch. If the electric motor is not stopped at once, the pinion *b* still remains out of mesh because the centrifugal force due to the weight *c* creates sufficient friction between *a* and *b* to cause *b* to turn with *a*. When the electric motor is finally stopped, the pinion *b* rocks on *a* until the weight *c* hangs downwards, as shown in (a).

In some cases, a gear reduction between the cranking motor and the engine is secured by means of a planetary transmission, very similar to that used in connection with the engine of a number of automobiles. As a general rule, the final drive to the engine crank-shaft is then by means of sprocket wheels and silent chain.

In case a dynamotor is used and fitted with a planetary transmission to obtain the necessary gear reduction for cranking, the same chain and sprockets are used when the dynamotor operates as a motor as when it operates as a generator; consequently, means must be provided by which the planetary transmission can be brought into action when the engine is to be cranked, and thrown out of action when the engine begins firing. In such a case, the dynamotor runs at a different speed in relation to that of the crank-shaft when running as a motor than when running as a generator. A planetary transmission for a dynamotor may be constructed so as to be thrown into action automatically or by hand at the will of the operator.

When an electric cranking motor is a separate unit, it may have its reducing gear permanently connected to the engine, but so arranged that it automatically comes into action by the rotation of the motor armature when it starts to crank the engine, and is automatically thrown out of action when the engine fires. The automatic action is always brought about by an overrunning clutch incorporated somewhere in the driving mechanism to the crank-shaft, most frequently a roller-type overrunning clutch is employed. It is customary to use an automatic starting transmission only in connection with engines where it can be so applied that the whole gear-train will be at rest while the engine is running under its own power; this excludes application to a cranking motor applied through a reducing gear-train to a flywheel gear. The reason for this is that at least one gear of the train would be revolved at extremely high speed by the flywheel gear, with which it is constantly meshed; this would produce an extremely disagreeable noise and also produce great difficulty of lubricating the gear driven by the flywheel gear.

An automatic starting transmission may consist only of spur gears, or it may be a combination of a spur gear and an internal gear, or it may be a planetary-gear set. In all automatic starting transmissions, all gears are permanently meshed.

ELECTRIC DETAILS

Single-Voltage and Multiple-Voltage Systems.—It is customary to designate the voltage of the electric automobile systems according to the number of cells in series in the storage battery, allowing 2 volts per cell, but as the voltage per cell when fully charged approximates 2.3 volts, the actual voltage at which the battery delivers current is somewhat higher than the nominal voltage of the system, and is still higher at the generator terminals while the battery is being charged by the generator. The nominal voltages employed are 6, 8, 12, 16, 18, and 24 volts.

When the motor uses current of the same voltage as the generator delivers to the battery, as well as to lights, and perhaps ignition, the whole system is called a *single-voltage* starting and lighting system. In some cases, however, the

motor uses current at a much higher voltage than is delivered by the electric generator to the battery. In other cases the motor and generator have a high voltage and the lamps use one-half that voltage; either combination is called a *double-voltage* system. In still other cases, the motor uses a much higher voltage of current than is delivered by the generator, and the lamps use a much lower voltage current than is delivered to the storage battery; thus, the motor in one system in actual use runs on a 24-volt current, the battery is charged by a 12-volt current, and the lamps are lighted by a 6-volt current. This combination is called a *triple-voltage* system.

Wiring Systems.—There are three wiring systems in use in automobile electric starting and lighting practice; these are the *single-wire* system, the *double-wire* system, and the *three-wire* system. The use of the last, at present, is confined to the electric-lighting circuits and electric ignition. It will sometimes be found that part of the electric installation in an automobile is wired in accordance with the one system, and the remainder in accordance with one of the other two systems. Thus, sometimes the motor is connected to the battery by two wires, while the generator and lamps are wired according to the single-wire system.

In a single-wire system, as implied by the name, the different pieces of apparatus are each connected to the current source by a single wire, the current returning to its source by ground connections; this system, owing to the simplicity of the wiring, is at present most favored by automobile manufacturers. In a double-wire system, current passes from the current source to each piece of apparatus by one insulated wire and returns by a second one.

The object of a three-wire system is to permit the use of low-voltage lamps or low-voltage ignition from a high-voltage battery and generator. Thus, an 18-volt battery can be so connected by means of the three-wire system that all 6-volt lamps can be used; or, a 12-volt battery can be used with 6-volt lamps. Furthermore, by the use of the three-wire system, a 12-volt or an 18-volt storage battery and generator can be used for an ignition system built for a 6-volt current, which voltage has become standard practice for battery ignition

systems. In a three-wire system a third wire called the *neutral wire* is connected to a connector between two intermediate cells of the storage battery. Thus, in a 6-cell battery, which has a nominal voltage of 12, there will be a nominal difference of 6 volts between the terminals of the end cells and the connector between the third and fourth cell, and consequently there will also be a nominal difference of potential of 6 volts between a wire connected to either end terminal and a wire attached to the connector between the third and fourth cell.

Reverse-Current Switches.—A reverse-current switch is intended to stop the passage of current from a storage battery through the generator whenever the voltage of the battery exceeds the voltage of the generator; this is done by opening the charging circuit between the battery and the generator. It closes the charging circuit again when the voltage of the generator exceeds the voltage of the storage battery.

There are several ways in which the charging circuit may be opened. One method is to have the operator of the car do this by hand every time the engine is stopped; this is done in the Entz and also in some Delco and Westinghouse electric systems. In these systems, the ignition switch is so constructed that the act of switching off the ignition also opens the circuit between the storage battery and the electric generator.

The most commonly used reverse-current switch is of the electromagnetic type and is operated both by voltage and by current.

Reverse-current switches are also called *cut-out relays*, *reverse-current relays*, *automatic cut-outs*, and *circuit-breakers*.

The principle of an electromagnetic reverse-current switch is shown in Fig. 3; the manner in which it is actually constructed naturally varies somewhat. The core *a* of an electromagnet carries two windings, of which the one *b* has many turns of fine wire and is connected across the brushes of the generator, that is, in shunt with them, so that there is the same difference of potential across the terminals of this winding that there is between the cables *c* and *d*. This coil of many turns of fine wire is called the *voltage coil* or *shunt coil*. A second coil *e* consisting of a few turns of heavy wire, and

called the *current coil*, and also the *series coil*, is in series with the cable *c* coming from the one brush of the generator, and has its one end connected to a contact *f* that is opposite a contact *g* carried by the armature *h*; this armature is electrically connected by the cable *l* to the corresponding terminal of the storage battery *i*. When the generator is disconnected from the storage battery, the contacts *f* and *g* are held apart by a spring *j* attached to the armature *h*.

As soon as the generator begins to generate, current passes through the voltage coil, and when the generator voltage

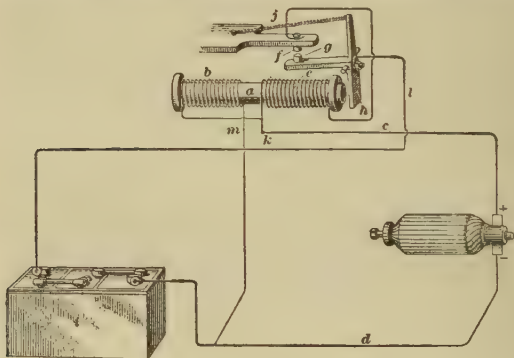


FIG. 3

has built up high enough, the energizing of the core *a* is sufficient to attract the armature *h*, overcoming the resistance of the spring *j*. This closes the contacts *f* and *g*, thereby closing the circuit to the storage battery. The current now passes through the current coil in addition to the voltage coil, and in the same direction, thereby still further energizing the core *a*; hence, the armature is more strongly attracted than before and the contacts *f* and *g* are held more firmly together. When for any reason the generator voltage falls below that of the storage battery, the latter sends out a reverse current; this passes

through the current coil *c* in the reverse direction from before, but passes through the voltage coil *b* in the same direction as current coming from the generator. The current coil and voltage coil are now opposed in their effect on the core *a*, which is thereby rapidly demagnetized until the tension of the spring *j* is greater than the attraction of the armature *h* by the core *a*; the armature is thereby pulled away from the core and the contacts *f* and *g* are separated, which opens the charging circuit.

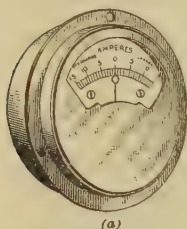
In Fig. 3 the series coil and shunt coil are so connected into the armature circuit that current from the generator passes only through the shunt coil until the series-coil contacts have closed. In many reverse-current switches of the electromagnetic type the two coils are so connected into the armature circuit that, even though the series-coil contacts are open, current coming from the generator passes first through the series coil and then through the shunt coil. With this connection, both coils exert a magnetizing effect on the core, and hence the contacts close very promptly.

Overcharging Switches.—The purpose of an overcharging switch is to prevent an overcharging of the storage battery, which is generally considered to be very harmful to the battery.

The overcharging switches used may be classified as *metering switches* and *manually operated switches*. The type first named was used to a large extent with the first Delco electric systems. Briefly, it was combined with an electric-current meter in such a manner that after a certain amount of current, which amount could be changed at will by the operator, had passed into the storage battery, the meter would automatically first reduce the charging rate and then open the charging circuit; it closed the latter again when a small amount of current had been taken from the battery. Manually operated overcharging switches are found in several American starting and lighting systems; they are usually so arranged that they will not only open or close the charging circuit, but will also stop all generation of current in the generator when they are opened.

Starting Switches.—A starting switch must form part of every electric system embodying electric cranking of the gasoline automobile engine. As implied by its name, it is used for starting the electric motor by closing the circuit

between the storage battery and the motor, in order that the motor may crank the engine; it also opens the circuit again when cranking is completed. In multiple-voltage electric systems the function of the starting switch is combined with that of the controller switch. In cases, however, where the electric motor drives the engine through a sliding-gear transmission, a second starter switch is fitted in some cases; the purpose of this switch is to start and rotate the motor armature at a low speed to facilitate meshing of the gears. A switch serving this purpose, while often called a starting switch, is more properly called a *low-speed switch*; it has no connection with cranking the engine, however, being used only in connecting the electric motor to



(a)

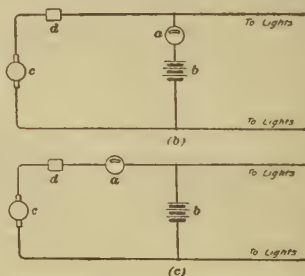


FIG. 4

the engine. In many cases the low-speed switch and starting switch are combined into a single-structure called a two-point switch, and so arranged that the first movement of the switch handle or button puts the low-speed switch into action, while any further movement of the switch handle or button closes the starting switch itself, so as to permit the motor or dynamotor to crank the engine. Electric cranking motors or dynamotors that do not use a sliding-gear transmission do not require a slow-speed switch. An electric motor may be started and stopped without using a separate switch for this purpose, by moving one brush away from the commutator to stop the motor and moving the brush into contact with the commutator

to start the motor; this is done in a number of Delco electric systems.

Ammeters.—Quite a number of automobile manufacturers install an ammeter with a charge and discharge scale, like that illustrated in Fig. 4 (a). As shown in (b), the ammeter *a* is usually connected into a branch leading to the storage battery *b*, and in series, so that current coming from the generator *c* and passing through the reverse-current switch *d* must pass through the ammeter, in order to pass into the storage battery, when it will indicate the rate, in amperes, at which it is being charged. Discharge from the storage battery, either toward the lighting and perhaps the ignition system, or toward the generator, is also indicated in amperes.

In some electric systems, as shown in (c), the ammeter *a* is placed directly into the main circuit instead of into a branch leading from the main circuit to the storage battery *b*. In this case, the ammeter will show the rate at which the generator *c* is furnishing current for the storage battery and lights, but will not show the rate at which the storage battery discharges current, except when the battery discharges toward the generator, as may occur if the reverse-current switch *d* should fail to open.

An ammeter reading up to not more than 30 amp. cannot be placed in series with the circuit running to an electric cranking motor, because the rate at which this draws current may run as high as 500 amp., and even more in some electric systems. For this reason, an ordinary low-reading ammeter is not fitted into the circuit of single-voltage electric starting and lighting systems employing a dynamotor with a single commutator, where the same wiring carries both the charging and the cranking current. Special ammeters for this purpose can be obtained, however, on special order placed with manufacturers of such instruments. With double-voltage dynamotor systems, an ammeter can be fitted if there is some part of the circuit through which only the low-voltage charging current passes; in that case, the ammeter will be placed in series with the low-voltage wire.

Many automobile manufacturers, instead of fitting an ammeter, fit a battery indicator, which simply reads "Charge," "Discharge," and "Off."

AUTOMOBILE GENERATOR REGULATION

Motor and Generator Windings.—In electric systems in which a separate cranking motor is employed, this motor is usually a series-wound machine; such a motor, together with its storage battery and its circuits, is shown in diagrammatic form in Fig. 5 (a). On closing the starting switch *a*, current passes from the positive terminal of the battery *b* through the field winding *c* to the positive brush of the motor *d* and through the armature winding and negative brush to the negative terminal of the battery.

The simplest electric generator with an electromagnetic field employs a shunt field winding, as shown in (b). When the generator armature is driven

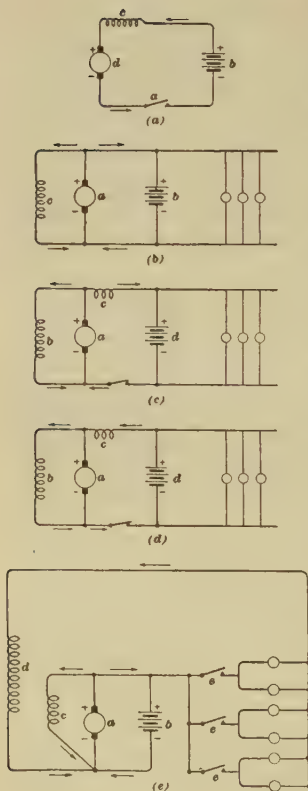


FIG. 5

sufficiently fast, current passes from the positive brush of the generator *a* to the positive terminal of the storage battery *b*, returning to the negative brush. Some current, however, passes from the positive brush of the generator through the *shunt field winding c* and back to the negative brush. The current passing through the shunt field winding energizes the pole pieces of the field. A plain shunt-wound generator can only be used in automobile work if it is driven at a practically constant speed.

In a number of automobile electric systems, differentially compounded generators are used; the principle of such a generator is shown diagrammatically in (c). The generator *a* has two field windings; the shunt winding *b* is connected across the positive and negative brushes of the generator, and a *reversed series winding c* is connected between the one brush and the corresponding terminal of the storage battery *d*. Current coming from the positive brush of the generator passes through the series winding in the reverse direction from which it passes through the shunt winding and, in consequence, the two windings oppose each other. Therefore, the magnetizing effect of the two kinds of field winding is equal to the difference between the magnetizing effects of each coil.

In some electric systems, the single-commutator dynamotor used is differentially compound-wound when running as a generator; the electric circuit is then exactly as shown in (c). When such a machine runs as a motor, as shown in (d), the current coming from the storage battery *d* passes through the series-field winding *c* in the same direction in which it passes through the shunt-field winding *b*. In consequence, the magnetizing effect of the shunt winding is increased by that of the series winding; that is, the two windings act cumulatively, and hence the machine when running as a motor is *cumulatively compounded*, although it is differentially compounded when running as a generator.

A generator may have its field wound with both a shunt winding and a series winding, the latter being so wound that current passes through it in the same direction it passes through the shunt winding. The magnetizing effect of the two field windings is cumulative, and consequently the machine is called an *accumulatively wound*, or *accumulatively compounded generator*.

Such a generator is open to the same objection as the plain shunt-wound generator; that is, that the voltage increases with the engine speed. For this reason, an accumulatively compounded generator, when used in automobile work, must be connected to the engine in such a way that it will run at a virtually constant speed, irrespective of the engine speed.

In (e), an accumulatively compounded generator is shown diagrammatically in connection with the storage battery and lighting system. Current from the positive brush of the generator *a* passes both to the storage battery *b* and the shunt field winding *c*, returning by way of the negative brush. The circuit through the series winding is open until one or more of the lighting switches *e* are closed, when current passes from the positive brush to the lighting switches and through the lamps to the series winding *d* and thence to the negative brush of the generator. The electric output of the generator is thus automatically increased when lamps are switched on.

The many different designs of electric generators with electromagnetic fields used in automobile work are all based on the simple forms of field windings that have been here explained.

Constant-Speed Regulation.—A method of regulating the current output and voltage of an automobile generator that was formerly used to some extent, was to construct the generator as a *constant-speed machine*, by which is meant that after the dynamo armature attains a certain speed it will run at that speed no matter how much the engine speed is increased. In practice, this is brought about by coupling the generator-armature shaft to the engine by means of a friction clutch operated by centrifugal force, which begins to slip as soon as the armature shaft reaches the speed the clutch-operating device is adjusted for.

While mechanical means of obtaining regulation other than the employment of a slipping clutch are possible and have been used abroad to a slight extent, they have not come into general use in American practice.

Differentially Compounded Field Regulation.—The operation of a differentially compounded generator may be briefly explained thus: The voltage generated by a generator depends on the *excitation* of the field and the speed of the armature.

In a plain shunt-wound generator an increase of armature speed increases the magnetic strength of the field. As a result, in such a generator even a comparatively small change of armature speed produces a comparatively large voltage variation, so that if the voltage is to remain constant under speed changes, the magnetic strength of the field must be weakened when the armature speed rises. This weakening of the magnetic strength of the field is accomplished by the reversed series-field winding. As soon as the voltage has built up enough for current to pass to the storage battery or lamps, this current in passing through the reversed series coil begins to *demagnetize*, that is, weaken the field, by tending to magnetize it in an opposite direction from that in which it is being magnetized by the shunt-field winding. The two field windings are so proportioned that beyond a certain armature speed their combined

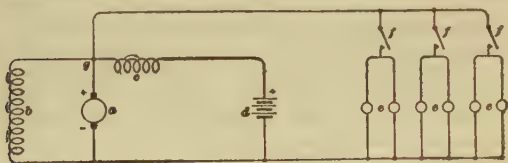


FIG. 6

effect tends to prevent any further increase in voltage as well as in amperage.

While only an approximate voltage regulation can be obtained by means of differential field windings, many manufacturers of electric systems consider the regulation actually obtained close enough for all practical purposes in automobile work, especially in view of the complete absence of external regulating devices.

A differentially compounded generator can be so connected to the lamps that an increased output is obtained whenever the lamps are turned on. Referring to Fig. 6, the generator is shown at *a*, the shunt-field winding at *b*, the reversed series-field winding at *c*, the storage battery at *d*, the lamps at *e*, and the lamp switches at *f*. While the lamp switches are open, the machine is working as a differentially compounded genera-

tor. One terminal of the lamp circuit is connected at *g* to one end of the series winding *c*. When the switches *f* are closed, the storage battery *d* furnishes part of the current to the lamps, and the current passes through the series coil in such direction as to assist the shunt coil in building up a strong magnetic field in the generator. The voltage of the generator is thereby increased and it will bear a larger proportion of the lamp load.

Regulation by Armature Reaction.—Suppose that a generator has a field winding so proportioned that the field becomes saturated at a fairly low armature speed. If this speed is increased, practically no voltage increase can be secured through greater field excitation, because the field is already magnetized practically to the limit, and hence a voltage increase can only occur through a higher armature speed. The brushes being stationary, then, the voltage increase in an armature coil under a speed increase is not directly proportioned to the latter, but is very much less, and in fact it becomes less and less as the armature speed increases. Consequently, voltage regulation can be effected by winding the field with a field winding that saturates the field at a low armature speed, and placing the brushes in the fixed position they should occupy to produce the greatest voltage in each armature coil at a very low armature speed. The voltage of the generator will then build up fast until the field is saturated; but after this as the armature speed increases, the voltage will build up slower and slower until a speed is reached where the voltage will not increase at all.

This method of preventing an excessive voltage is spoken of as *voltage regulation by armature reaction*.

Regulation by Third Brush.—Voltage and current output regulation of an automobile generator can be obtained partly by armature reaction and partly by the use of an auxiliary brush or brushes placed between the regular brushes carrying the current from the armature coils to the storage battery, etc. These auxiliary brushes are called *interbrushes*; when only one auxiliary brush and two main brushes are used, the auxiliary brush is usually spoken of as the *third brush*, and the control is referred to as *regulation by third brush*.

With a third brush, to which one end of the shunt field is connected, the other end being connected to one of the main

brushes, the action is as follows: As the armature speed is increased, assuming the resistance of the armature circuit to remain constant, armature reaction causes the brush position of greatest voltage to shift forwards, but as all three brushes remain stationary the voltage increase is not directly proportional to the speed increase but very much less, and this voltage increase becomes less and less as the armature speed is increased more and more, finally ceasing entirely. When the armature speed is increased still further, the brushes lag so far behind their best position that the current in both the shunt circuit and the armature circuit is reduced and the magnetic field so weakened that the voltages of both circuits drop. From this it follows that the current output of a generator with inter-brush regulation at first increases with the speed of the engine driving it and then becomes reduced when the engine speed increases beyond a certain maximum.

Regulation by Fixed Resistance.—It is possible to obtain a constant voltage or a constant current over a large variation in the armature speed by means of a single resistance coil that is alternately placed in series with the shunt winding of a generator and short-circuited by means of an electromagnetic device.

If the energizing coil of the device is connected across the brushes of the generator, a substantially constant voltage will be maintained; and if the coil is placed in series with the armature circuit, the result will be a practically constant current output.

The energizing coil of the regulator attracts an armature against the resistance of a spring; this armature when attracted by the core of the energizing coil opens a pair of contacts and thereby cuts a fixed resistance into the generator shunt field circuit, thus cutting down the field excitation; as soon as this occurs the decreased magnetization of the energizing coil core releases the armature, closes a pair of contacts, and thereby short-circuits the fixed resistance, thus increasing the field excitation. These vibrations of the armature occur very rapidly, probably as high as 150 times a second.

Regulation by Variable Resistance.—Close regulation can be obtained by putting a variable resistance in series with the

shunt-field winding, the resistance being least when the engine speed is low, and being high when the engine speed is high. The variable resistance, by weakening the magnetic field more and more under armature speed increases, prevents the voltage or current increasing beyond that for which the machine has been designed. As a general rule, all automobile generators, no matter what the voltage of the system, are designed to begin charging the battery at a car speed of about 8 to 10 mi. an hr. on high gear. As a matter of course some generators will begin charging at a higher or lower speed than here given.

Either a constant voltage or a constant current can be maintained by means of a variable resistance, depending on the means by which this is actuated.

Regulation by means of a variable resistance was widely used at one time, but has been abandoned in favor of a simpler method of regulation, such as by third brush, for instance.

Methods of Changing Generator Output.—A number of manufacturers of automobile electric systems consider it advisable to provide means by which the generator output can be varied to suit different conditions under which the automobile is used. Thus, if a car is driven very much in the daytime and the electric starter is used but very little, there is but little current taken from the storage battery, and a quite low rate of current output of the generator will keep the battery fully charged; an advantage of such a low current rate is that there is little danger of overcharging the battery and harming it thereby. On the other hand, if an automobile is used chiefly at night, when some or all of the lights are required, the current taken from the storage battery while the car is standing or being driven very slowly with the lights turned on, is very large, and consequently a fairly high charging rate is needed in order to keep the battery fully charged.

In a number of electric systems employing generators with differentially compounded field windings, a so-called *charging-shunt resistance wire* is placed in parallel with the reversed series winding. This charging-shunt resistance wire can be changed for a larger wire of the same length, which has a lower resistance; consequently, if this is done less current passes through the reversed series winding, lessening its opposition

to the shunt-field winding, and therefore the voltage and current output of the generator are increased. By substituting a charging shunt having a greater resistance, the current output and voltage of the generator are decreased.

With the third-brush system of generator regulation, provision is often made for changing the generator output by shifting the third brush.

It is generally inadvisable to change the generator output or time at which charging begins without communicating first with the makers of either the car or the electric system, asking their advice in the matter. The reason for this is that failure of the storage battery to be fully charged at all times may not be due to too low a charging rate; thus, the storage battery may be short-circuited through a ground, or the commutator of the generator may be very dirty, or brushes may be stuck in their holders and consequently make poor contact on the commutator, or the reverse-current switch may be stuck, thereby forming a direct short circuit for the battery, etc. In most cases, running the car more in the daytime, or being a little more sparing in the use of the lamps, or eliminating the needless use of lamps, especially of the headlights, or cutting down the current consumption by using higher efficiency lamps, will prove that the generator output as regulated at the factory is just right for all-around work.

LAMP BULBS

The Ediswan base, two forms of which are shown in Fig. 7, has become the standard lamp base for automobile work, although lamp bulbs with a screw base are occasionally found on the older cars. It has a plain cylindrical brass base $\frac{1}{2}$ in. in diameter and $1\frac{1}{8}$ in. in length over all, with two short pins *a* set diametrically opposite, as shown in (a) and (c). The sockets, which have an inside diameter of $\frac{5}{8}$ in., have two slots opposite each other, as shown in (b) and (d), the slots being curved at their inner ends to form a hook *b*. The base is slipped into the sockets with the pins *a* inserted in the socket slots and pushed in as far as it will go against the resistance of plungers *c*, each of which is held out by a helical spring inside the socket, after which the lamp is turned right-handed so as to hook the pins

behind the hooks *b*. The plunger or plungers *c* press outwards against the lamp base and thus hold it firmly in place. To remove the lamp the operation is reversed.

The lamp base shown in (a), and its socket in (b) are known as the *Ediswan double-contact base and socket*; the two contacts *d* are insulated from the shell and the ends of the filament are connected to these two contacts. The two wires bringing the current to the socket are electrically connected to the two plungers *c* of the socket. Double-contact base lamps and sockets are intended to be used for double-wire and three-wire systems, but can be used in a single-wire or ground-return

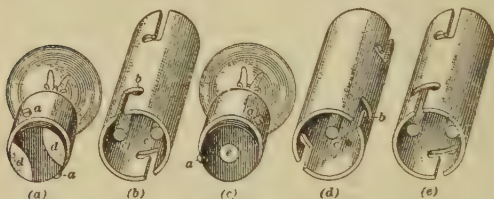


FIG. 7

system by running a grounding wire to ground from one of the plungers.

The *Ediswan single-contact base and socket*, shown in (c) and (d), are intended to be used in single-wire or ground-return systems. The one end of the lamp filament in (c) is connected to the shell and the other end to the central contact *e* that is insulated from the shell. The socket has a single central contact plunger *c*, as shown in (d), to which the wire bringing the current to the socket is connected. The shell of the socket is then grounded to the lamp or other fixture in which it is placed, which fixture in turn must be grounded to the frame of the car.

Single-contact sockets are also made for double-wire systems, in which case one wire connects to the central plunger of the socket and the second wire to the shell.

Ediswan sockets that contain a switch are in use; these are known as *switch-type sockets* and also as *on-and-off sockets*. A double-contact on-and-off socket operated by turning the lamp bulb is shown in (e).

Ediswan single-contact and double-contact bases have the same external dimensions and consequently will interchange in their respective sockets; a single-contact base lamp bulb will not make contact in a double-contact socket, however, nor will a double-contact base lamp bulb make contact in a single-contact socket.

Ediswan base lamp bulbs are made in different voltages, candlepower, and sizes and shapes of bulbs, and also with carbon or tungsten filaments, the latter being almost universally used. Nitrogen-filled lamp bulbs with Ediswan base in single-contact and also in double contact type can also be obtained; these nitrogen-filled lamp bulbs use only about one-half the current per candlepower that is used by tungsten lamps, give a much whiter light, and permit a better focusing in parabolic reflectors.

ELECTRIC SYSTEM CIRCUIT DIAGRAMS

In many Delco single-voltage inherent regulation electric systems, current regulation is secured by means of a third brush, the shunt-field winding being connected to one of the main brushes and to a third brush. A dynamotor of the double-commutator type is employed, and the wiring is in accordance with the single-wire, or ground-return, system.

The electric-circuit diagram of the Delco system under discussion, and employing only dynamo-and-storage-battery ignition, is shown in Fig. 8. The storage battery *a* is connected in parallel with both the motor commutator *b* and the generator commutator *c*, the motor circuit being open as long as the brush *b'* does not touch the motor commutator. The series field winding of the motor part of the dynamotor is shown at *d*. A switch *e* incorporated with the dynamotor opens and closes the generator armature circuit; it is interconnected mechanically with the brush *b'* in such a manner that the generator circuit is closed when the motor circuit is open, and is open when the motor circuit is closed.

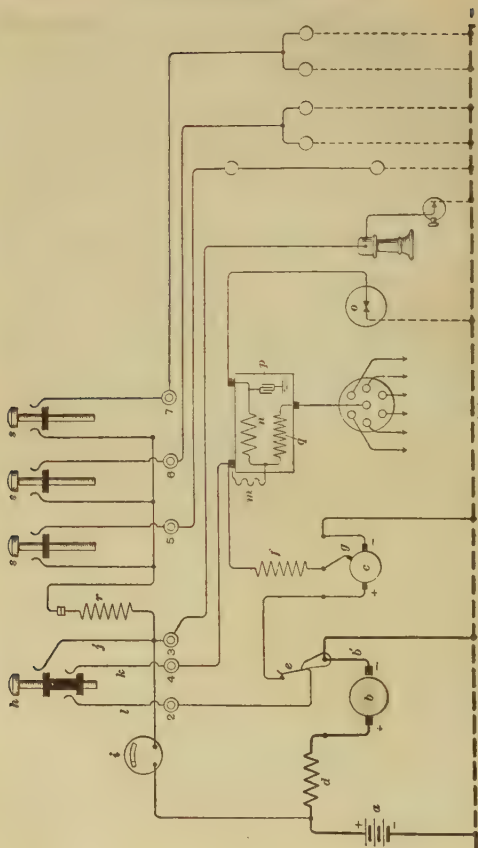


FIG. 8

The shunt-field coil f of the generator is connected to a third brush on the commutator and to the positive main generator brush; the shunt-field circuit as well as the generator-armature circuit are opened and closed whenever the ignition is switched off or on by pushing in or pulling out the ignition switch button h . An ammeter i showing charge and discharge is connected into the generator and the storage battery circuit; it is incorporated directly into the combined lighting and ignition switch. Owing to the way it is connected into the circuit the ammeter does not show the current consumed by the lights, horn, and ignition when the current is supplied by the generator, but shows the current consumed by these accessories when it is supplied by the storage battery a .

With the engine at rest the pulling out of the ignition button h , Fig. 8, closes the generator circuits, so that current passes from the positive terminal of the storage battery through the ammeter i , through the switch blade j and switch-button contacts to the switch blades k , l , and thence simultaneously through the field and armature circuits of the generator to ground and back to the storage battery. At the same time the ignition circuit is closed through the ignition resistance unit m , primary ignition coil winding n , timer contacts o , and ground. The result of closing the generator circuits is that the storage battery drives the generator slowly as a motor, thus permitting easy meshing of the starting transmission gears. Sending current from the storage battery through the generator is often spoken of as *motoring the generator*. Operation of the starting pedal in the car now meshes the transmission gears and at the same time opens the generator-armature circuit at the switch e and closes the motor circuit by dropping the brush b' on the motor commutator; the generator shunt-field circuit remains closed by way of the negative generator brush and ground. In consequence, the dynamotor now runs as an accumulatively compounded motor, cranking the engine. As soon as the engine fires, the starting pedal is released; this unmeshes the starting transmission, lifts the motor brush b' off the motor commutator, and closes the generator armature circuit at the switch e . The dynamotor now runs as a generator.

No reverse-current switch is fitted, as a general rule, as stopping the engine by pushing in the ignition-switch button *h* also opens the generator-armature and field circuits. The condenser, which protects the ignition timer contacts *o*, is shown at *p*, and the secondary winding of the ignition transformer coil at *q*. The Delco circuit-breaker, which indicates a short circuit in the lighting and horn circuits by buzzing, is shown at *r*, and the three lighting switches at *s*. In this particular diagram no provision is made for dimming the headlights, small auxiliary headlights connected to terminal 7 of the switch being used instead. Bright or dim headlights at will can be had, however, by connecting a dimming resistance between terminals 6 and 7, in which case no auxiliary headlights or side lights are used.

Some Delco dynamotors employing a third brush for generator regulation differ slightly from the one described in that both motor brushes are simultaneously lifted from the motor commutator to open the motor circuit, and both are dropped simultaneously on the motor commutator to close the motor circuit. The principle of operation of the system as a whole does not differ in any respect, however, from the one described.

The electric-circuit diagram of a two-unit Delco electric system is shown in Fig. 9; that of a three-unit system does not differ from it. In the particular electric-circuit diagram presented in Fig. 9 no provision is made for dimming the headlights *a*, small auxiliary bulbs *a'* of a low candlepower being fitted for city driving. However, on cars not provided with auxiliary headlights a resistance for dimming the headlights is connected between the terminals 6 and 7 of the combined lighting and ignition switch, on which is also mounted the ammeter *b*. A cowl light is shown at *c* and the tail light at *c'*. Different forms of combination switches are used with the two-unit and three-unit Delco systems, some being of the pull-button and some of the rotary type.

The starting motor *d* and generator *e* are in parallel with the storage battery *f*; a single-wire system is employed. The starting motor is a series-wound four-pole machine with four field coils *g*, *h*, the coils *g* being in series with each other by way of the commutator and armature winding, as are also the

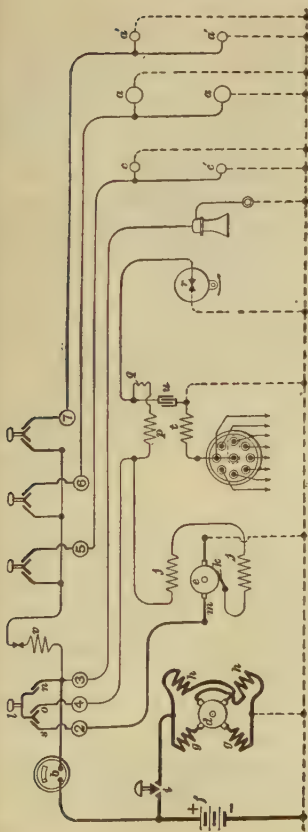


FIG. 9

coils *h*; the field coils *g* are in parallel with the coils *h*. By this arrangement of the field coils a very compact and powerful motor is obtained, as placing the coils in parallel permits passing a large current through the motor. The starting switch is shown at *i*; as cranking connection of the motor to the engine is made by the Bendix inertia clutch, there is no necessity of making provision for running the armature slowly at first, as is done in Delco systems using a motor-generator. The two coils *j* of the generator shunt-field winding are connected in series, one lead being connected to the third brush *k* and the second lead being brought out by way of the ignition coil to the terminal 4 of the ignition switch *l*. The field winding, when

the ignition switch *l* is closed, is connected to the main brush *m* of the generator by way of the cable coming from the terminal *2*; the shunt field is thus seen to be connected across the main brush *m* and third brush *k*. As a general rule, no reverse-current switch is fitted, as pushing in the ignition-switch button *l* not only opens the ignition circuit, thus stopping the engine, but also opens both the generator armature circuit and generator shunt-field circuit, thus preventing the storage battery from discharging itself through the generator. Some Delco two-unit and three-unit systems of the type here shown are fitted with a reverse-current switch, the current coil of this switch being in series with the cable carrying the charging current to the battery, and the voltage coil being connected across the two main brushes of the generator. Also, in some two-unit and three-unit Delco systems the shunt field of the generator is not connected to the ignition switch, but inside of the generator to the one main brush, and consequently the shunt-field circuit is not opened by cutting off the ignition, although the generator armature circuit is opened thereby.

To start the engine, the ignition-switch button *l*, Fig. 9, is pulled out, thus permitting current from the positive storage-battery terminal to pass through the ammeter *b* and switch blade *n* to switch blade *o*, to terminal *4*, to primary winding *p* of induction coil, through resistance unit *q* to timer contacts *r*, to ground, to negative terminal of storage battery. As the closing of the ignition switch also closes the generator circuits, some current will pass by way of the switch blades *o* and *s* through the generator, tending to run this as a shunt-wound motor. To prevent excessive current discharge through the generator it is essential promptly to close the motor-starting switch *i* as soon as the ignition is switched on, and to release the starting switch as soon as the engine fires. With the engine running, the path of the charging current is from the positive main brush *m* of the generator to terminal *2*, to switch blade *s*, to switch blade *n*, to ammeter *b*, to positive terminal of the storage battery, from negative terminal to ground, to grounded main brush of the generator. The generator shunt-field current passes from positive main brush *m* to switch blade *s*, to switch blade *o*, to field coils *j*, to negative third brush *k*. In

cases where the shunt field is not connected to the ignition switch, the shunt-field current passes directly from the positive main brush through the field coils j to the negative third brush k . Ignition current when furnished by the generator passes from the positive brush m to switch blade s , to switch blade o , to and through primary winding p of the induction coil, to and through resistance unit q , to timer contacts r , to ground, to grounded negative main brush of generator.

The secondary induction coil winding is shown at t , the condenser at u , and the circuit breaker for the lights at v .

About the only condition under which dry cells would be used for ignition is where the storage battery cannot furnish current, either on account of being completely exhausted, or because of a broken terminal or cable, or on account of having been removed from the car for repairs, and it is necessary to run the car in spite of this. The first step is to render the generator inoperative by opening the shunt-field winding, which is done by disconnecting one of its leads; if this precaution is omitted there is great danger of burning out the generator. The next step is to disconnect the cable to the generator at the terminal 2 , Fig. 9, of the combination switch and to connect to terminal 2 a wire from the one terminal of the dry-cell battery. The second terminal of the dry-cell battery is connected by a wire to ground. Obviously the engine must be started by hand cranking.

An *Auto-Lite* motor and generator, together with a *Connecticut* ignition system, is shown in Fig. 10. A ground return, that is, a single-wire system, is used for everything excepting the starting motor, the ground for each apparatus being shown at a . The ground shown at the starting motor b is for the purpose of grounding the negative terminal of the storage battery c . The motor-starting switch is shown at d ; the reverse current switch e has its voltage coil grounded, as shown. The shunt-field winding of the generator f is not grounded, but the armature circuit is grounded in order to complete the circuit to the storage battery c . An ammeter g is connected into the generator-and-storage-battery circuit, and shows the charging rate when the engine is running, and the discharge rate when the lamps are lighted with the engine either stopped

or running very slowly. The primary ignition current does not pass through the ammeter in this particular case, the ignition switch *h* being connected directly to the positive terminal of the storage battery. The two head lamps *i* and the tail lamp *j* having in series with it the cowl lamp *j'*, are controlled by a combination lighting switch *k*, which is fitted with a resistance coil *l* for dimming the head lamps. The induction coil of the ignition circuit is shown at *m*, the timer at *n*, and the distributor cap at *o*. The electric horn *p* has a small series-wound motor controlled by the horn button *q*.

If an engine with an Auto-Lite third-brush generator is to be run with the storage battery removed, the two terminals on the generator should be connected together with a piece of

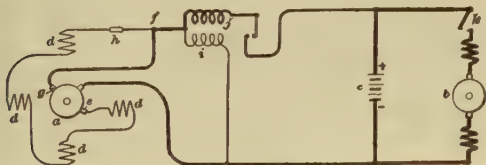


FIG. 11

copper wire of about 10 gauge. This short-circuits the generator and thereby prevents burning out the field windings.

The electric-circuit diagram of a *Leece-Neville* system of the third-brush regulation type, is shown in Fig. 11, the lighting, ignition, and horn circuits being omitted for the sake of clearness. The generator *a* and starting motor *b* are in parallel with the storage battery *c*. The four shunt-field coils *d* are in series; one end of the shunt-field winding is connected to the third brush *e*, and the other end to a terminal *f* which in turn is connected to one main brush *g*. The shunt-field fuse is shown at *h*. This fuse, being in series with the shunt-field winding, protects the field against burning out. Removal of this fuse opens the shunt-field circuit, and permits the engine to be run safely when the storage battery is disconnected. In the actual machine, the fuse will be found beneath the cover

of the reverse-current switch. The reverse-current switch is mounted on top of the generator, and has the usual voltage coil i and current coil j . The motor-starting switch is shown at k .

The electric circuit of a *Gray & Davis* third-brush generator electric system is shown in Fig. 12. The generator a is a 6-volt four-pole machine carrying the two series-connected shunt-field coils b on two opposite poles. One end of the shunt-field winding is connected to the positive main brush c and the other end to the third brush d . The two main brushes are at right angles, and a series-wound armature is used.

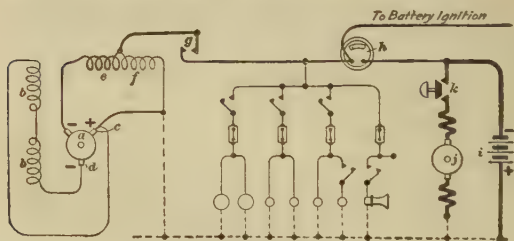


FIG. 12

Moving the third brush toward the positive brush decreases the current output, and moving it toward the negative brush increases the current output. The reverse-current switch is located directly above the generator commutator; it contains the usual current coil e and voltage coil f , the contacts being indicated at g . The positive brush, as well as the voltage coil, is grounded to the frame of the generator. An ammeter h indicates the net charging current passing to the storage battery i . The starting motor j is series-wound; the starting switch is shown at k . The starting motor is connected to the engine flywheel gear by a Bendix inertia clutch. The positive brush of the motor is grounded, as is also the positive terminal of the storage battery. Lamps and horn are also grounded. Two different types of lighting switches are

furnished regularly by Gray & Davis; in the round type a single fuse is used for the two headlights, another fuse for the two auxiliary lights, a third fuse for the cowl and tail light, and a fourth fuse for the horn, etc. In the square type of lighting switch, each lamp, horn, etc. has its own fuse. Ignition may be from a generator-and-storage-battery ignition system or by a magneto.

A Remy electric system employing a separate motor and generator, the latter having the third-brush method of current-output regulation, uses a thermostat which when the generator becomes warm places a resistance in series with the shunt-field winding, and when the generator is cold cuts out this resistance. The current output of the generator is thus decreased in warm weather, and increased in cold weather, the demand on the storage battery for current usually being greater in cold weather. The thermostat is shown in Fig. 13. A stamped steel bracket *a* carries a coil *b* of resistance wire, and a blade *c* is fastened at one end to the bracket

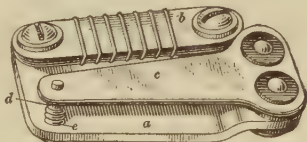


FIG. 13

a, but is insulated therefrom. The blade *c* carries a silver contact point *d*, which at low temperatures is held by the spring tension of the blade against a second contact *e* in the bracket *a*. The blade *c* is of spring brass welded to a strip of nickel steel, the brass strip being placed toward the contact *e*. As brass expands far more than steel when heated, heating of the blade causes it to curl upwards, thereby separating the contacts *d* and *e*. The thermostat is adjusted so it will separate the contacts *d* and *e* when the temperature inside the generator reaches approximately 175 degrees F. The one end of the resistance coil *b* is electrically connected to the bracket *a* and the other end to the blade *c*; this blade is connected electrically to the ungrounded main brush of the generator, and the bracket *a* to the field winding and thence to the third brush; the resistance is thus in series with the field winding, but is short-circuited whenever the contacts *d*, *e* are closed.

In the third-brush Remy systems, two different four-pole motors are used. The one motor, shown at *a*, Fig. 14 (*a*), has four series-field coils, the two coils *b* being in series and the two coils *c* also being in series; the two sets of coils *a* and *c* are in parallel. In the motor shown at *a* in Fig. 14 (*b*), the four series coils *b* are all in series. In other respects, the two

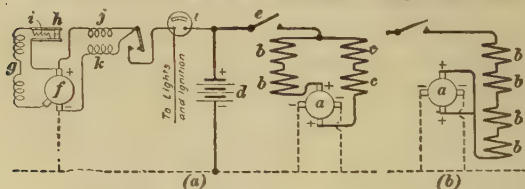


FIG. 14

systems are identical. A ground return circuit is employed for the motor, generator, etc. In some cars the positive terminal, and in other cars the negative terminal is grounded.

The motor-starting switch is shown at *e*, the generator at *f*, the shunt-field winding at *g*, the thermostat at *h*, the resistance

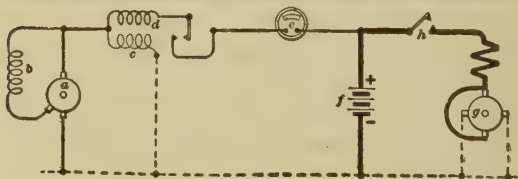


FIG. 15

coil at *i*, the current or series coil of the reverse-current switch at *j*, the voltage coil of the same instrument at *k*, and the ammeter, if one is used, at *l*. The current for lights, ignition, etc. is usually taken from the ammeter, as shown, which should be of the zero center type, that is, show charge and discharge. To protect the generator in case it is necessary to run the engine with the storage battery removed, the shunt-field winding should be opened.

The electric-circuit diagram of a *Wagner* two-unit electric system is shown in Fig. 15, with the lighting, ignition, and horn circuits omitted. The generator *a* has third-brush regulation; the shunt-field winding is shown at *b*. The reverse-current switch has the usual voltage coil *c* and series coil *d*; either an ammeter or a battery indicator *e* is usually fitted between the generator and the 6-volt storage battery *f*.

The starting motor *g* is a series-wound four-pole four-brush machine, which is connected to the engine for cranking either through an overrunning clutch or through a Bendix inertia clutch. In some cases the starting motor itself is grounded, as shown in the illustration, but in other cases a separate grounding cable connects the one pair of motor brushes to the ground.

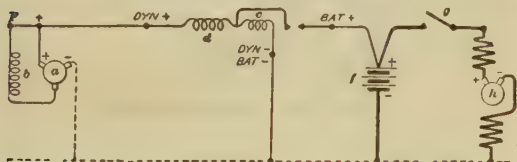


FIG. 16

As a general rule, the positive terminal of the storage battery is grounded. The starting switch is shown at *h*.

If the engine must be run with the storage battery disconnected, the generator should be short-circuited by running a piece of No. 10 copper wire from the generator terminal to the ground; this will protect the generator against burning out. Provision is made on the generator for changing the current output by shifting the third brush.

A number of different cars use the Dyneto electric systems having a separate motor and generator. The motor is a four-pole machine, has a series-field winding, and employs a series-wound armature, the two brushes being 90 degrees apart. The generator is also a four-pole machine with a series-wound armature and two main brushes 90 degrees apart; current regulation is by means of a third brush. The electric-circuit diagram is shown in Fig. 16, where *a* is the generator having

its negative main brush grounded, *b* is the shunt-field winding, *c* is the reverse-current switch voltage coil, and *d* the current coil. In some cases the reverse-current switch is a unit separate from the generator; in such cases the voltage coil is grounded by a wire running from the terminal *DYN-BAT*-to ground. When the reverse-current switch is incorporated with

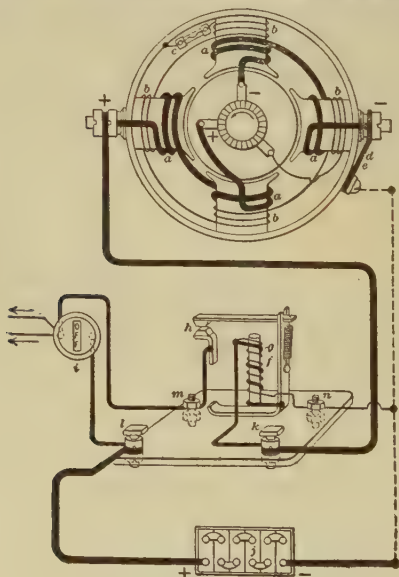


FIG. 17

the generator, the voltage-coil ground connection is made at the factory. The shunt-field connection to the positive main brush is made on the outside of the generator; this makes it easy to open the shunt field to protect the generator in case it is nece-

sary to operate the car with the storage battery disconnected. The storage battery is shown at *f*, the starting switch at *g*, and the starting motor at *h*.

The electric-circuit diagram of the Type 3554-G-1, Model G, *North East* electric system, is shown in Fig. 17, with the horn, lighting, and ignition circuits omitted. Each pole piece of the motor-generator carries a series coil *a* wound to buck the shunt coil *b* when the machine is running as a generator. The four series coils *a* are in series, as are also the four shunt coils *b*. One end of the shunt-field winding is grounded and fitted with a removable fuse *c*; this grounded end is connected to the negative main brush by way of the ground strap *d*, the negative motor-generator terminal, and two of the series coils, as shown. The other end of the shunt-field winding is connected to the third brush. The engine can be run safely with the storage battery removed, either by removing the field fuse, or by bridging the negative and positive terminals by a piece of No. 10 wire.

The charging rate can be reduced slightly by shifting the third brush toward the negative brush, and increased by shifting it away from the negative brush. An ammeter must be connected to the motor-generator, and the engine cranked by hand to prevent burning out the ammeter, after changing the brush. Readings are taken before and after the change of position. The ammeter is removed immediately after the adjustment is made.

AMMETERS AND VOLTMETERS

For the testing of automobile electric equipment, ammeter equipment having the following ranges should be provided: 0 to 300 amperes, for measuring cranking current, 0 to 30 amperes, for measuring charging current, current taken by all the lamps and the ignition system, etc.; 0 to 3 amperes for current measurement of individual lamp circuits, ignition circuit, etc. The voltmeter equipment should have the following range: 0 to 30 volts, used chiefly for testing the voltage of storage batteries and generators; 0 to 3 volts, used for testing the voltage of single storage-battery cells and for testing

coils for open circuits and ground; 0 to 90 or 100 millivolts ($\frac{9}{100}$ to $\frac{1}{10}$ volt), used for armature testing.

If testing instruments covering the ranges here given are provided, it will be possible to make tests on all electric starting and lighting systems used on American cars since the year 1912. For a garage specializing only on a single electric system, however, probably such a wide number of ranges as given above is not required. Thus, suppose a certain electric system is 6 volts (nominal), with a maximum current output of 10 amperes. Then, a voltmeter having a range of 0 to 10 volts and an ammeter having a range of 0 to 15 amperes will be sufficient for practically all testing, excepting armature and storage-battery-cell testing, for which a millivoltmeter having a range of 0 to 90 or 100 millivolts and a voltmeter having a range of 0 to 3 volts is required.

High-grade electrical testing instruments are exceedingly sensitive, and great care must be taken not to use a low range connection to measure a high voltage or amperage current; thus, if current from a 3-volt circuit is sent through the instrument when connected to show a maximum of 100 millivolts, the instrument will probably be burnt out promptly. Likewise, measuring a 30-ampere current with a 3-ampere shunt will damage the instrument. If the probable voltage or amperage of an electric circuit is not known, the measuring instrument should be connected up to give the highest range and a trial reading taken to see if it is safe to use a lower range of indication. Thus, if the instrument is connected up to give the 30-volt range and the trial reading is 2 volts, it is safe to use the 3-volt range.

Garage testing instruments unless otherwise specified are intended for direct current; they can therefore be used for measuring the primary ignition current used in generator-and-storage-battery ignition systems, but cannot be used for measuring the voltage or amperage of the primary current supplied by an automobile magneto. When alternating-current testing instruments are desired, specific instructions to this effect should accompany the order.

AUTOMOBILE TIRES

TIRE CONSTRUCTION AND APPLICATION

PNEUMATIC TIRES

The tires used on automobiles may be divided into two general classes; namely, pneumatic and solid tires.

Pneumatic tires may be divided into three types, namely, regular clincher, quick-detachable clincher, and quick detachable straight side tires, and their difference lies chiefly in the makeup of the bead. A *regular clincher* tire has a soft, extensible bead that permits of its being stretched over a one-piece rim; a *quick-detachable clincher* bead is constructed of hard rubber and fabric rendering it inextensible, and the tire can be used only on a split or a removable side ring rim; the *quick-detachable straight side* tire is also made with inextensible beads. In this type, the beads are usually made of braided or cable wires built into a core of semi-hard rubber and fabric with no hooks or heels such as appear on the quick-detachable clincher, but are flush with the outside surface of the tire casing. This difference in construction is the real distinction between the two types. A regular clincher tire can be used on a quick-detachable clincher rim, but the reverse is not true, since the stiff bead of the quick-detachable clincher tire cannot be stretched over the one-piece rim. The use of regular clincher tires is confined to the smaller wheel sizes, because they work just as well in these sizes and are somewhat cheaper to build. Regular clincher tires of larger sizes are not used because, with their soft beads, they will not stay on the rims, and, consequently, either quick-detachable clincher, or quick-detachable straight-side tires, are used. The latter type of tire is in most common use.

In Fig. 1 is shown a short section of a pneumatic tire of the *regular clincher type*. The casing, or shoe, *a* of the tire is open along the side next to the rim *b*. The middle of the rim is nearly flat and the edges are curved inwards toward each

other, as at *c*, so as to form a clinch on each side. The casing *a* is formed with soft extensible beads *d* that fit into the clinches of the rim. An inner tube *e* of soft rubber is placed inside the casing. This inner tube retains the air in the tire. The pressure of the compressed air forces the beads of the casing into the clinches of the rim and retains them there. The tread *h* is the part that comes in contact with the roadway when the tire is in regular use.

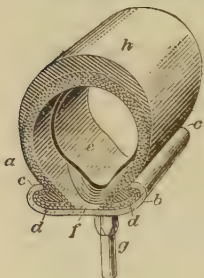


FIG. 1

clincher tire. Therefore, to prevent the inner edges of the casing from expanding appreciably in diameter when the tire is inflated endless wires, shown projecting from one edge of the casing at *a*, are employed. One or more removable rings *b* and *d* that form part of the wheel rim are provided to hold the casing in place. After removing the rings *b* and *d*, the complete tire can be slipped off sideways from the wheel rim. This form of tire is also known as the *flat-base tire*.

The universal quick-detachable rim shown in Fig. 2 is adaptable to both clincher and straight side tirers which allows the motorist to choose his type of tire, and increases his chances of securing service in emergencies.

A universal quick-detachable rim with a *quick-detachable clincher tire*, is shown in Fig. 3. In this case, the rubber filler strip *f*, Fig. 2, is removed and the solid ring *b* is reversed, giving the rim the appearance of a regular clincher rim.

Removable, or demountable, rims are rims that can be removed

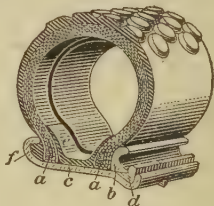


FIG. 2

from the wheel. By having the rim demountable, a complete spare tire can be carried inflated on an extra rim, so that the arduous work of changing the tire on the rim and inflating it is eliminated.

Demountable rims are made in one solid piece to take regular soft-bead clincher tires, and they are also made to take straight-side and clincher quick-detachable tires; in the latter two cases they are known as *quick-detachable demountable rims*.

Rims should frequently be painted with shellac or a mixture of glycerine and graphite. The latter, while more expensive, is the better for it not only is not affected by mud and water, but makes almost a perfect lubricant. However, any good metal paint containing no oil is much preferable to nothing at all.

In removing the tire from the rim, a rubber hammer will do less damage than an iron or lead one.

The *carcass*, or body, of a pneumatic tire is built up of a number of layers of fabric, when it is known as a *fabric tire*, or it is built of several layers of cords, and called a *cord tire*.

The *Schrader tire air valve*, which is the valve in common use, is illustrated in Fig. 4. The stem head *a* is inside the inner tube, and a metal washer *b* is clamped down against the tube by means of the nut *c*, which fits on the threaded body of the large hollow stem *d*. A guard, or *spreader*, or *bridge clip*, *e* is placed between the washer *b* and the nut *c* to prevent the inner tube from coming into contact with the nut *c*. The nut *g*, when tightened, presses the washer *h*, which may be of either leather or rubber, against the felloe. The cap *k* protects the valve from dust, and at the same time provides an air-tight joint that prevents loss of air from the inner tube, in case the air check-valve should leak. Leakage of air is prevented by the rubber packing disk, or washer, *l*, which bears against the end of the valve stem when the cap is screwed in place. A large dust cap *m* screws over the larger portion of the stem against the leather washer *n*, and thus forms a protection for the entire end of the stem, which would otherwise be exposed.

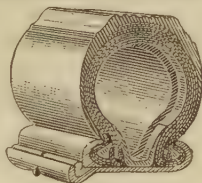
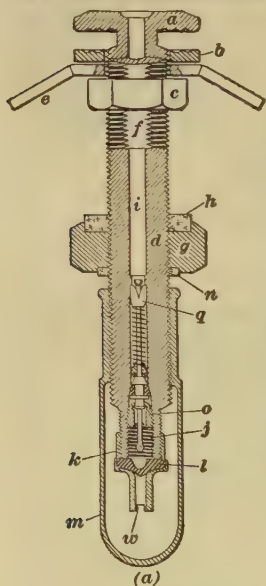


FIG. 3

As shown in the enlarged view (b), the valve is provided with a short threaded piece *o* that screws into the end of the valve stem *d*. When this piece is screwed down to the proper position, as shown in view (a), the conical rubber packing ring *p*, view (b), presses against a corresponding coned surface



in the hole *i* through the stem, and at the same time a thin, brass, cup-shaped piece *q* bears against a square shoulder farther down in the hole through the valve stem, so as to compress the coiled expansion spring *r*, and thus force the valve *s* up toward the valve seat *t*. The valve *s* is provided with a soft-rubber valve disk *u*, against which the comparatively sharp edge of the valve seat *t* bears when the

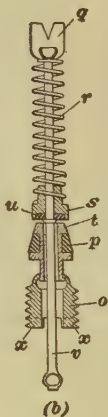


FIG. 4

valve is closed. The packing ring *p* makes an air-tight joint against the coned internal surface of the bore of the valve stem.

Valve Sizes.—Special size valves are required for certain sizes or kinds of rims and tires, and it is necessary to obtain the proper ones for use in casings for which the tube is intended.

The following is a list of valves for different cases: Schrader No. 777, for 3-inch regular clincher tires; Schrader No. 97, for 3½-inch tires, clincher or quick-detachable; Schrader No. 792, standard equipment for tires 4 inches and larger; Schrader No. 1822 for all wire-wheel tires.

The repair of valve insides should never be attempted. At the first warning of disorder, they should be removed and replaced by new ones. The valve insides, themselves, should not be depended upon entirely to keep up the air pressure in the tire. The small rubber washers in the valve caps must be in good condition, so that the cap will make an air-tight seal on the tire valve, when screwed tightly in place.

TIRE MAINTENANCE

INFLATION

One of the most important things in the care of automobile tires is to keep them properly inflated. The only practical way to determine whether a tire is sufficiently inflated is to use a pressure gauge. Furthermore, if the bad results of under-inflation are to be avoided, it is not enough to test the pressure at long and varying intervals but a regular and frequent test should be made, say, twice a week.

Fixed rules are used by some manufacturers for determining the proper air pressure for different sized tires. For instance, the Diamond Rubber Company uses the rule that the required air pressure per square inch equals the diameter of the cross-section of the tire multiplied by 18. Thus, a 36"×4" tire requires an inflation pressure of $4 \times 18 = 72$ lb. per sq. in., by this rule. Other manufacturers use different constants varying from 15 to 21, while in still other cases no definite rule is followed, tables being compiled from experience.

The accompanying table gives the inflation pressures recommended by the Firestone Tire and Rubber Company, as well as the safe load for front and rear wheels on a car without passengers. The pressures given are for fabric tires

LOAD AND AIR PRESSURE FOR PNEUMATIC TIRES

Size of Tire Inches	Air Pressure Pounds per Square Inch	Load per Wheel. Pounds	
		Rear	Front
28×3	50	350	450
30×3	50	375	475
32×3	50	375	475
34×3	50	400	500
36×3	50	425	525
29×3 ¹ / ₂	60	450	550
30×3 ¹ / ₂	60	475	575
31×3 ¹ / ₂	60	500	600
32×3 ¹ / ₂	60	525	625
33×3 ¹ / ₂	60	550	650
34×3 ¹ / ₂	60	575	675
36×3 ¹ / ₂	60	625	700
30×4	70	550	700
31×4	70	575	725
32×4	70	600	750
33×4	70	625	775
34×4	70	650	800
35×4	70	675	825
36×4	70	700	850
37×4	70	725	875
38×4	70	750	900
40×4	70	800	950
42×4	70	850	1,000
32×4 ¹ / ₂	80	800	1,000
33×4 ¹ / ₂	80	850	1,050
34×4 ¹ / ₂	80	900	1,100
35×4 ¹ / ₂	80	950	1,150
36×4 ¹ / ₂	80	1,000	1,200
37×4 ¹ / ₂	80	1,050	1,250
38×4 ¹ / ₂	80	1,100	1,300
40×4 ¹ / ₂	80	1,200	1,400
42×4 ¹ / ₂	80	1,300	1,500
33×5	90	950	1,200
34×5	90	1,000	1,250
35×5	90	1,050	1,300
36×5	90	1,100	1,350
37×5	90	1,150	1,400
38×5	90	1,200	1,450
39×5	90	1,250	1,500
41×5	90	1,350	1,600
43×5	90	1,450	1,700
36×5 ¹ / ₂	95	1,250	1,500
37×5 ¹ / ₂	95	1,300	1,550
38×5 ¹ / ₂	95	1,350	1,600
40×5 ¹ / ₂	95	1,450	1,700
37×6	100	1,350	1,600
39×6	100	1,450	1,700
41×6	100	1,550	1,800

Cord tires, as a general rule, can safely be run at a pressure 25% below that recommended for fabric tires, in the absence of any specific information issued by their manufacturers.

If an automobile is run at high speed for any length of time, the tires will be heated considerably and the air pressure within them will thus be slightly increased. Although this increase of pressure does not endanger a new tire of good quality, some tire repair men claim it will do harm to an old tire that has become weakened by long use. It is therefore advisable to reduce the air pressure in such tires by slightly opening the tire air valve.

TIRE PROTECTORS AND ANTISKID DEVICES

There are a number of tire protectors on the market, designed to be placed over the tread of a tire, to protect it partly against puncture and partly against abrasion and other damage through contact with sharp stones, etc. in the road. Most of these protectors are in the form of endless leather bands, usually three-ply, studded with hardened steel studs around their circumference. Some of these protectors are designed to hook to the clinches of clincher rims; others are held in place merely by the inflation pressure, being shaped to fit the tire tightly when the latter is deflated. From time to time protectors made of fabric and rubber, and designed to be held in place by the inflation pressure, have been and are being placed on the market.

A serviceable tire protector can be made by placing a worn-out casing with a fairly good tread over a regular tire, cutting off both beads of the tire that is to serve as a protector. For best results the protector thus made should be thoroughly sewed to the tire beneath it; in all the larger cities can be found concerns specializing on this work and having a sewing machine especially built for it. Such concerns generally also keep in stock tires known as *double-tread tires*, made by sewing two tires together.

Although tire protectors and double-tread tires reduce the liability of punctures, they slightly reduce the resiliency of the tire as well, and therefore have a tendency to slightly increase the gasoline consumption.

In addition to detachable tire protectors with steel studs, there are many forms of tread designed to prevent tires from skidding, and tires with such forms of tread are known as *antiskid tires*. Each tire manufacturer has his own form, some forms consisting of raised bars or knots of various shapes, while others consist of variously shaped depressions. There is no doubt that any of these special antiskid treads greatly reduce the liability of skidding, and also, owing to the greatly increased thickness of the tread, the liability of puncture.

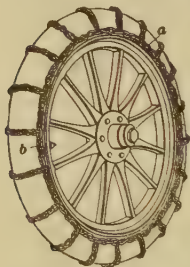


FIG. 1

For driving on very muddy, slippery, or icy roads, most automobile owners and drivers prefer chains around the tires, at least on the two rear wheels. The best-known chain device is that called the *Weed antiskid tire chain*, which in Fig. 1 is shown in place on a pneumatic tire; this type of chain has been used extensively and has given entire satisfaction. The complete chain consists of two circumferential chains, one of which is shown at *a*. These chains pass around the

wheel just outside the rim, and are connected together by numerous cross-chains that pass over the tread of the tire. The ends of the circumferential chains are fastened together by means of very simple fasteners *b*, one of which is provided in each chain. Both fasteners lie between the same pair of cross-chains. To put the chain in place, the wheel is jacked up or the chain is stretched out on the ground or floor, either in front of or behind the wheel, and the wheel run on it. The chain can then be brought over the wheel and fastened in place. To remove the chain, the fasteners are opened and the chain is permitted to drop to the ground, after which the wheel is run from it.

Under no consideration whatsoever should an antiskid tire chain be fastened to the rim or spokes of the wheel, as this will seriously injure the tire; it must be left perfectly free to creep around the latter.

TIRE DETERIORATION

TIRE DETERIORATION THROUGH IMPROPER INFLATION

If a tire is not sufficiently inflated to keep it nearly round when carrying the weight of the car and the passengers, it is subject to rapid wear both alongside the bead at the rim of the wheel, called *rim cutting*, and throughout the body of the tire, on account of the constant bending of the fabric.

If a tire is extremely soft on account of complete or nearly complete deflation, it flattens at the bottom where it rests on the roadway, taking a form similar to that shown in Fig. 1. All the load is then practically carried by the clinch of the rim or by the retaining rings or flanges, as the case may be. The result is that the casing is injured by rim cutting where the clinch or retaining rings bear on it, and the inner tube may be cut through in places where it is pressed together just over the clinch or retaining rings. In addition to this, the heads of the tire

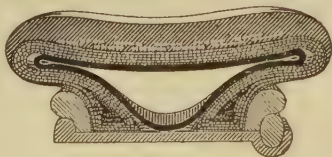


FIG. 1

lugs in a plain clincher type, as well as the valve stem end inside the rubber tube, are liable to be injured, especially if the roadway is very uneven or rocky.

A tire that has become deflated on account of leakage at the valve, a puncture, or abrasion should never be run. If no spare tire is available, the rim may be wrapped with rope or the car may even be run on the bare wheel rim. While this may spoil the rim, wheel rims are very cheap in comparison to tires.

A test for leakage through the air valve can be made by immersing the end of the valve stem in water contained in a glass or some other vessel. A leak is indicated by bubbles forming in the water. A little saliva placed on the end of

the valve stem will also show up a leak in the air valve after the cap is removed from the stem. A leak through the cap of the valve stem is almost invariably due to deterioration of the small rubber disk packing in the cap, the disks being cut through or wrinkled on account of screwing the cap into place. The simplest remedy for such a leak is to use a new cap.

MISCELLANEOUS CAUSES OF TIRE FAILURE

Tire Wear Through Improper Driving.—Either skidding the wheels on a dry road by a too powerful application of the brakes or causing the wheels to spin by starting the car too suddenly, is extremely injurious to the tires.

Pulling Loose of Tire Fabric.—A tire shoe sometimes fails because the fabric pulls loose along the outside of the shoe just above the angle between the bead and the main body of the tire. The fault can be readily detected by bending the bead of the tire down by hand while the tire is off the wheel.

Chafing of Inner Tube.—Chafing of the inner tube is a frequent source of tire trouble. The chafing ultimately rubs a hole completely through the tube, so that it becomes deflated. The best, and probably the only, way to prevent a tube from chafing is to use a liberal quantity of some such substance as talcum powder, French chalk, powdered soapstone, or flake graphite.

Blisters.—Blisters, which frequently form on the tire shoe, are due to various causes. If a tire is faulty, the kneading action created by rolling over the road sometimes works the outer coating of rubber loose from the outer layer of fabric. Another cause of a blister is a cut through the outer coating of rubber. Sometimes a blister is caused by a puncture in the inner tube. Thus, the escaping air passes through the shoe until it reaches the outer covering of rubber and then raises a blister.

Additional Causes of Undue Tire Wear.—Permitting tires to stand on an oil-soaked floor, letting a car stand for months unused on inflated tires, improper alinement of the wheels, will all cause an undue and rapid deterioration of tires.

PRESERVATION OF TIRES IN STORAGE

If an automobile is to be laid up for some time, say a week or so, it is an excellent plan to take the weight off the tires by putting the machine on four blocks or jacks; in fact, many owners do this every time they come in from a run.

If an automobile is to be laid up for a long time, say for the winter, it is advisable to remove the tires and inner tubes from the rims. The casings should then be thoroughly cleaned and carefully examined both inside and outside, and all needed repairs made at a properly equipped tire-repair establishment, unless, of course, the operator has the facilities and is capable of making the repairs himself. After removing all rust and dents, the rims should be painted. The tires may then be replaced on the rims and slightly inflated. The weight should be taken off the tires by placing four blocks or jacks under the axles; also, the place in which the machine is stored should be dry and not subject to extremes of temperature.

If a machine must be stored in a damp or a very hot or very cold place for a long time, it is advisable to remove all tires to a dry place that has a fairly even temperature. It is well also not to expose them to direct sunlight.

The greatest enemies of tires and tubes in storage

are intense light, exposure to heat in excess of 75° F., and dampness. Guarding against these by selecting a proper place for storage will obviously prolong the life of the tires.

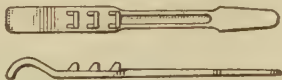


FIG. 1

TIRE REPAIRS

REMOVING AND REPLACING TIRES

Tire Tools.—Several tools are required to remove and replace a regular clincher tire with rapidity and ease. For tires up to, say, 3½ in. in cross-section, a pair of tools of the form shown in Fig. 1 or a pair of tools of the form shown in Fig. 2 may be used; both tools are called *tire irons*, or *tire prodders*

If work on clincher tires is to be carried on to any great extent, one of the many patented tire tools could be used to advantage. The *detaching tool* shown in Fig. 3 can be used to



FIG. 2

force the shoe loose from the rim. In Fig. 4 is shown the *Continental tool*, together with its application to force the bead of a tire away from the rim to permit insertion of tire irons. If the casing has rusted fast to the rim, as is usually the case when the tire has not been removed for a long time, sometimes the work of removal can be expedited by taking off

the wheel. The casing should never be struck with a hammer. If it is found impossible to insert one of the tire irons, a soft piece of wood, shaped on the end to conform to the shape of the casing just outside the wheel rim, should be

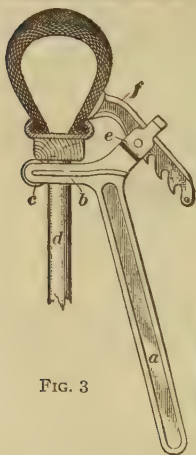


FIG. 3

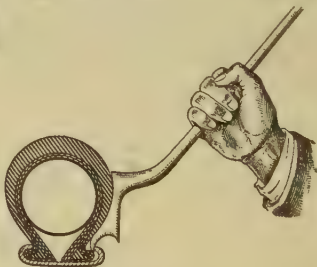


FIG. 4

placed against the casing and struck by a hammer. After the tool is once inserted, the remainder of the bead can usually be loosened by drawing the tool along the inside of the rim.

A very convenient tool for removing a clincher tire or replacing it is the tire fork shown in Fig. 5. This is for the purpose of lifting the shoe to permit the removal or insertion of the tire lugs and the inner-tube valve stem.



FIG. 5

Removing the Inner Tube.—One of the most important things to bear in mind when removing or replacing a tire is that the inner tube must be handled with great care. In

order to remove a tire, first jack up the wheel so as to relieve the tire of its load; then deflate the tire, if deflation has not already occurred, as on account of a puncture or a leak. Remove the large nut from the tubular stem of the valve, and push the stem in through the wheel rim. Insert the thin point of a

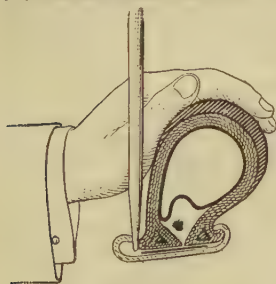


FIG. 6

tire iron and loosen the bead all the way around. Next, work the tire toward the outer edge of the rim, so as to permit removal of the tube. After all of the tube except the part at the valve stem has been removed, insert two tire irons as far as possible under the shoe, one tool on each side of the valve stem, and between the casing and tube. The outer ends of the handles of the tools can then be brought together and the

tire lifted up with one hand on the tools, while the valve stem is removed from the rim with the other hand.

In case of a puncture, the casing should be marked in the neighborhood of where the puncture occurred, and the hand should be run around inside the casing for the purpose of locating a tack or nail that might still be sticking in the casing.

Before putting in another tube, the inside of the shoe should be cleaned so as to remove all loose dirt and sand. Both the tube and the inside of the shoe should be sprinkled lightly with talcum powder, French chalk, or powdered soapstone before putting them together, and the inner tube should be deflated.

Replacing a Shoe.—A new shoe and inner tube can be put on in two ways. One way is to put the tube inside the casing first, and then put them both on together; the other way is to put one bead of the casing on the rim first, and then put the inner tube in place, as when putting a new tube in a tire that has had only one side removed from the wheel. It is probably better for the novice to adopt the latter method.

Inserting an Inner Tube.—To insert an inner tube, first lift the shoe at the opening in the rim through which the air valve passes in the same manner that it was lifted to remove the valve of the old tube. Then insert the valve of a new tube in the hole through the rim and work in the remainder of the tube by hand, taking care not to twist it. As soon as the inner tube has been put in the shoe, it should be inflated slightly. The bead should then be forced back into the rim by means of the proper tool.

CHANGING TIRES WITH DEMOUNTABLE RIMS

Removing Rim from the Wheel.—The first step in removing a demountable rim is to jack up the car sufficiently to allow clearance for the inflated tire when replaced. The rim wedges *a* are then removed by means of the brace wrench, as shown in Fig. 7. The valve stem dust cap and locknut are then removed, and the wheel turned until the valve stem is at the top. The tire is pulled out at the bottom until it frees the wheel, after which it is raised perpendicularly to free the valve stem from the felloe, being careful not to bend the stem.

Removing Tire From Rim.—After the tire and rim are removed from the wheel, be sure that all air is expelled from the tire before attempting to take it off the rim. The method of removing the tire from one type of rim is shown in Figs. 8 and 9, and this method is common to practically all types of

demountable straight-side rims. Fig. 8 shows the first operation. The tire and rim are placed flat on the ground and the cam lock *a* is disengaged. A screwdriver is inserted between the tire and the rim, bridging both sides of the rim, and the screwdriver handle is pressed in enough to bring one end of the rim above and overlapping the other end. Then, the knee or



FIG. 7

foot is placed on the tire as shown in Fig. 9, and the rim is pulled upward and separated from the tire to the point where

the valve stem projects through. The rim and tire may now be completely separated, taking care not to damage the valve stem.



FIG. 8

If the tire has not been off the rim for a time, the two will probably be rusted together, and cannot readily taken apart, as described. In such cases, a tire tool or blunt screw driver should be inserted

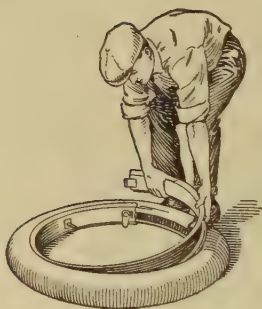


FIG. 9

between the rim and the tire near the loose end of the rim, and the tire pried down while the rim is pried up. This operation is continued all around the rim, or until a sufficient leverage is obtained to permit of pulling the rim from the tire, as shown in Fig. 9. In prying the rim loose in this manner, care must be taken that the inner tube is not damaged.

There are devices on the market for removing and replacing split rims as just

described, and when much of this work is to be done, one of these devices can be used to advantage. These devices range from small hand tools to large stationary machines.

Replacing Tire on

Rim.—Before replacing a tube, the usual inspection for nails, glass, etc., should be made in the casing, the interior of the casing sprinkled with talcum, and the tube inflated enough so that it will hold its shape and not be pinched. The tube protector strip should be inserted with the



FIG. 10

end of the strip containing the hole for the valve stem placed in last.

The tire with its partly inflated tube is then placed on the floor, or on a clean spot on the ground, the valve stem is

slipped into its hole in the rim, and the rim and casing are turned over, bringing the rim on the bottom. Starting from the end of the rim nearest the valve stem, as much of the tire

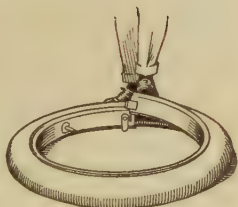


FIG. 11

as possible is forced on the rim with the hands. A stiff screwdriver or tire tool is sometimes necessary to pry the tire into position, as shown in Fig. 10. When the tire is all in place except the end carrying the key lock, this end



FIG. 12

can be pressed into place as shown in Fig. 11. A screwdriver is inserted between the ends of the rim as shown in Fig. 12, and the cam lock *a*, Fig. 8, is turned to its original position.

Remounting Rim on Wheel.—When mounting a demountable rim on the wheel, turn the wheel so that the valve hole in the felloe is at the top. The valve stem

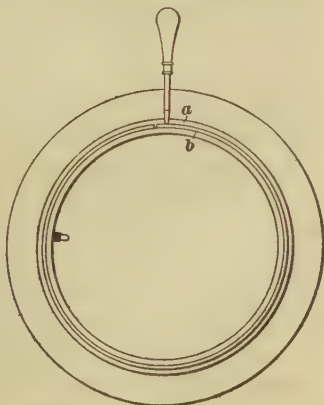


FIG 13

may then be inserted and the lower part of the rim swung into place. The clamps should be tightened by first giving each nut one or two turns with the wrench and then going around the wheel again, tightening up fully each nut.

QUICK-DETACHABLE DEMOUNTABLE RIMS

Removing From Wheel.—The rim is removed from the wheel in the same manner as described for a straight demountable rim. The rim and casing are then laid on the floor or ground with the locking ring up.

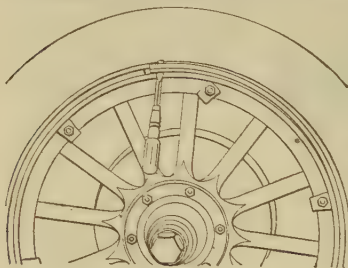


FIG. 14

Removing Tire From Rim.—After making sure that the tube is deflated, a screwdriver is inserted between the solid ring *a*, Fig. 13, and the split or locking ring *b*. For the sake of clearness the tire and rim are here shown in a vertical

position. When an opening is obtained between the two rings, a coin or other convenient piece of metal should be dropped into this opening, so as to hold the opening when the screwdriver is removed. The screwdriver is then inserted in the slot under the locking ring as shown in Fig. 14, and the locking ring pried out. The side ring and tire may then be removed from the rim.

Replacing Tire on Rim.—After replacing repaired tube in the casing, as previously described, the casing is placed on the rim, the solid side ring is slipped into place, and the locking ring applied by engaging the pin in the notch in the rim, and then forcing the locking ring into its groove around the wheel.

ROADSIDE INNER TUBE REPAIRS

Cement Patches.—Patches for inner-tube repairs can be bought ready cut in various sizes, or they can be bought in

the strip. In repairing a small puncture in a tube, the bloom, or velvety surface, is removed by rubbing the part of the tube around the hole with coarse emery cloth or sandpaper. The surface is then cleaned with gasoline and a good rubber cement is spread thinly over the part of the tube that is to be repaired. The cement should be allowed to dry until it becomes thick in consistency, or *tacky*, as it is called, which means that it is very sticky when one's finger is applied to it.

The fabric is removed from the surface of the patch and the surface is moistened with gasoline. The patch is then applied carefully to prevent air bubbles, and after it is once in place it must be compressed to make sure that all parts are in contact. This can be done by laying the patched portion on the running board, and rolling some round object such as a screwdriver handle over it.

A patch put on in this manner will not hold nearly so well as a properly vulcanized repair.

No-Cement Patches.—To repair a puncture in an inner tube with the *no-cement patch*, or the *self-cementing patch*, it is necessary only to buff the tube around the puncture with emery cloth and clean with gasoline. The linen cover is then removed from the patch, the gum side moistened with gasoline, and the patch applied to the tube. It should be pressed down firmly for a few minutes, when the tube can again be put in service. Various sizes of no-cement patches can be obtained.

ROADSIDE CASING REPAIRS

Tire Dough.—Casings can be made to render longer service by examining them every few days, and taking care of any small cuts before they have a chance to do any serious damage. Several different substances, selling under the trade names of *plastic*, *cure cut*, etc., are on the market for this purpose. The cut or hole is first cleaned of all dirt and washed with gasoline. The inner surface is then given a coating of cement. A piece of the tire dough large enough to fill the opening is taken from the can and kneaded with the fingers until plastic like putty. It is then worked into the opening in the casing, and allowed to set for 15 or 20 minutes. Repairs so made will permit of the car being driven for many miles without

further trouble. Of course, this applies only to small cuts, and when there are large holes, or they extend through the tire fabric, vulcanization is the only safe procedure.

Inside Casing Patches.—One style of patch is shown separately in Fig. 15 (a), and in place in the tire casing in (b). The wide flaps make adjustment of the patch easy, and hold

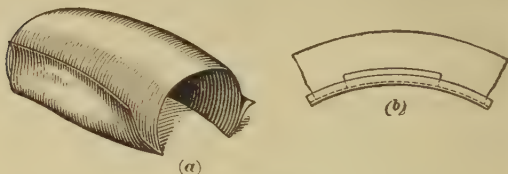


FIG. 15

it in position, preventing creeping. A form of inner repair patch shown in Fig. 16 is suitable to protect the casing, in case of bruises, small cuts or punctures. It is applied by cleaning the inside of the casing with gasoline, roughening the surface with emery cloth, and applying three coats of patching cement, letting each one dry before the other is put on. The wax paper is removed from the patch, and the face thus exposed is moistened with gasoline.



FIG. 16

Outside Casing Protectors.

If the cut in the shoe is large, it is advisable to put an *outside protector patch* over the tire. Protector patches, also called *manchons*, made for this purpose

are on the market. One form of patch is provided with eyelets and a lace, so that it can be laced into place, as illustrated in Fig. 17 (a) and (b). In applying the laced-on patch, it is advisable to have a part of the lace around a spoke of the wheel, as shown in (b), to prevent the patch creeping.

If the cut in the casing is comparatively small and deep, as when made by a small piece of glass, it should be probed with

some small instrument as soon as it is discovered, if glass still remains in it, and the glass, if found, should be removed.

PROPER METHOD OF CARRYING INNER TUBES

To carry an inner tube, it should be fully deflated and then closely folded or rolled and put into an oilcloth casing or box. It can, of course, be deflated by rolling it up. When deflating a tube in this way, the valve insides should be removed during the operation to let the air escape. As soon as the inner tube is deflated the valve insides should be replaced so that no air will enter the tire before it can be folded. The successive steps of folding a tire into a bundle are illustrated in Fig. 18. It is best to cover the valve stem with an ordinary rubber finger cap, or with a cap of some other material, such as chamois skin or cloth. The tube should not be carried loose among tools, nor be placed where oil or gasoline can get on it. It very often happens that an inner tube will deteriorate more rapidly when carried as a spare than when in use in the casing, because of carelessness in the method of carrying it. The tube should never be folded while wet, should be sprinkled lightly with talcum or powdered soapstone, and held in its container in such a manner as to prevent chafing.

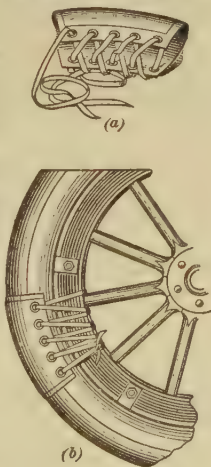


FIG. 17

OVERSIZE TIRES

The fact that tires are often loaded beyond their capacity by automobile operators, has led to the design of so-called *over-*

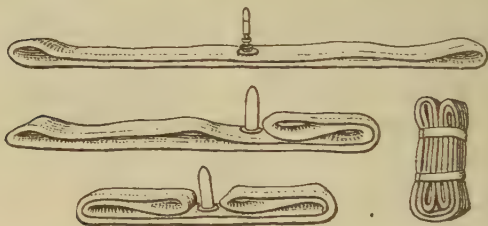


FIG. 18

size tires, which are made to fit standard rims without any change whatsoever. Oversize tires are usually 1 in. larger in

OVERSIZED TIRES TO FIT STANDARD RIMS

Standard Sizes Inches	Oversizes Inches	Standard Sizes Inches	Oversizes Inches
28×3	29×3 $\frac{1}{2}$	36×4	37×4 $\frac{1}{2}$
30×3	31×3 $\frac{1}{2}$	34×4 $\frac{1}{2}$	35×5
32×3	33×3 $\frac{1}{2}$	36×4 $\frac{1}{2}$	37×5
30×3 $\frac{1}{2}$	31×4	38×4 $\frac{1}{2}$	39×5
32×3 $\frac{1}{2}$	33×4	42×4 $\frac{1}{2}$	43×5
34×3 $\frac{1}{2}$	35×4	36×5	37×5 $\frac{1}{2}$
36×3 $\frac{1}{2}$	37×4	36×5 $\frac{1}{2}$	37×6
32×4	33×4 $\frac{1}{2}$	38×5 $\frac{1}{2}$	39×6
34×4	35×4 $\frac{1}{2}$	40×5 $\frac{1}{2}$	41×6

diameter and $\frac{1}{2}$ in. larger in cross-section than the standard-size tire they are intended to replace. Standard-size tires are always made to an even number of inches in diameter; oversize tires are always made to an odd number of inches in diameter.

MOLDED AND HAND-WRAPPED TREADS

If a molded tread is to be produced on a tire, the carcass of the tire is covered with the unvulcanized tread stock and the whole tire is then enclosed in a cast-iron mold of the required shape, a circular spring or an air bag, which is simply a heavy inner tube made for this purpose, having been placed inside the casing. The mold with the enclosed casing is then placed into a steam kettle and heated until the rubber is vulcanized. If a hand-wrapped tread is to be produced, no mold is used, but the tread stock is held in shape during vulcanizing by wrapping the uncured casing tightly with long strips of muslin.

AUTOMOBILE MANAGEMENT AND MAINTENANCE

AUTOMOBILE OPERATION

GENERAL INSTRUCTIONS

Spark and Throttle Manipulation.—The manipulation of the spark and throttle levers is one of the most important things to be understood by the driver. The speed can be decreased either by partly closing the throttle or by retarding the spark. But neither of these methods alone will answer if the speed is to be decreased any great amount. If the speed is decreased simply by retarding the spark, the gases escaping from the engine will be extremely hot; this will generally be evidenced in a short time by the boiling of the cooling water; besides, the exhaust pipe becomes hot when the throttle is well open and the spark retarded so as to be very late.

If the spark is left unchanged and the throttle is closed as the speed decreases, the ignition will be too early. At the slow speed this will generally cause a knocking or pounding sound in the engine. The spark lever should never be left in such a position that ignition will take place early enough to cause pounding. The correct way to decrease the speed of the engine is to close the throttle and to retard the spark.

To speed up the car quickly again, the spark, if far advanced, should first be retarded somewhat and the throttle then opened. As the speed increases the spark should be advanced, always keeping it at the position that gives the greatest running effort, or power, for the corresponding speed of the engine. In climbing a hill, the adjustments are practically the same as when increasing the speed on a level road; that is, the spark is first retarded slightly and the throttle then opened so as to maintain the desired rate of travel. This presupposes that the hill is not steep enough to require changing to a lower gear. For a given rate of travel the spark can be farther advanced when the throttle is well closed than when it is open.

When the ignition system is fitted with a fully automatic spark control, no attention to the spark timing on the part of the driver is required or possible, as no spark-control lever is fitted. Some ignition systems are fitted with a semiautomatic spark control, in which an automatic governor normally controls the spark; but a separate hand spark-control lever is also fitted. This lever is then used for conditions beyond the range of the automatic control governor.

Most cars are fitted with both a hand throttle lever and an accelerator pedal for controlling the power developed by the engine. In cars thus fitted, it is the usual practice to employ the accelerator pedal entirely in driving. There is no objection, however, to using the hand throttle lever in driving, yet most persons find the use of the accelerator pedal more convenient. One great argument in favor of the use of the accelerator pedal, is that it closes the throttle automatically when the service brake is applied, thus preventing the engine from racing when the clutch is released.

Starting.—To start the engine, make sure that the speed-change gears are in the neutral position, and that the emergency brakes are set. Set the spark lever in the late, or retard, position, excepting with some magnetos, where the maker's instructions should be followed, and open the throttle half way or less (with some carbureters the throttle must be fully closed). Switch on the ignition and make sure that the gasoline is turned on so it can flow to the carbureter; remember that the engine cannot fire without gasoline.

If it becomes necessary to crank the engine by hand, it is safer to use the left hand, standing with the left side turned a little toward the car, but because the left arm is seldom strong enough, the right arm is used by most drivers. Grasp the handle so that the thumb is folded up against the fingers, as shown in Fig. 1 (a), and not around it, as shown in (b); then a back kick will simply open the fingers. As soon as the engine has started, close the throttle as much as possible; never allow the engine to race. If the engine fails to start on the combustible charges remaining in the cylinders, it will generally be necessary to crank somewhat rapidly, giving a quick pull on the crank so as to draw in a combustible mixture from the carbureter.

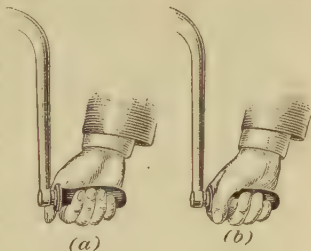


FIG. 1

Two or more pulls on the crank are generally required to get a fresh charge into one of the cylinders and ignite it.

Modern magnetos give a hot spark at low engine speeds, but occasionally an old model is encountered in which no such provision is made, and in such cases, the engine will have to be *spun*, as it is called; that is, turned over very rapidly a half a dozen times in order to get sufficient speed of the magneto armature to generate a spark. When a battery ignition system is fitted, starting is independent of the speed at which the engine is run. If no provisions are made for choking the air supply to the carbureter, the carbureter should be primed if the engine does not start with proper cranking. If there is no priming device on the carbureter, place one hand, a glove, or a cloth over the air intake so as to obstruct the air passage partly. Modern carbureters are provided with a butterfly valve for temporarily obstructing the air-inlet passage while cranking the motor. The obstruction of the air intake causes more suction at the gasoline nozzle. A number of the more

recent carbureters are so constructed that no priming is necessary.

Modern cars are fitted with an electric motor by which the engine is cranked. These motors are started in various ways, some by depressing a starting button on the footboard or pulling out a switch button on the dash or cowl board, and others by turning a switch handle. In any case it must be remembered that the starting motor only takes the place of hand cranking, and that, if it turns the engine over, the motor has done all it can do.

As soon as the engine begins to fire, the throttle should be closed somewhat and the spark advanced. At first, when the engine and the carbureter are cold, the engine will run irregular, but as it becomes warm it will run steady and then the throttle can be closed more. The engine will not develop its maximum power until the cylinders and the carbureter are warmed up properly. If, in cold weather, the throttle is closed too soon the engine is liable to stall, even though the throttle is opened more as soon as the slowing down is noticed. Stalling is due to the fact that the carbureter is not able to supply a sufficiently rich mixture at a low engine speed while the fuel is still cold. If the carbureter is fitted with a dash control or a steering-post control for enriching the mixture, enriching should be done when starting a cold engine, making the mixture leaner again as soon as the engine and the carbureter warm up.

Stalling of the engine immediately after starting is most pronounced with engines having the carbureter located very low and not fitted with a hot-air intake.

Running a Car with Sliding-Gear Transmission.—To start a car fitted with a sliding-gear transmission, when the hand throttle lever is in its extreme closed position, and after the brakes have been released, the clutch pedal is pressed forwards far enough to bring the clutch brake into action, and the gear-shift lever is then placed into its first-speed, or low-gear, position. If no clutch brake is fitted, it is well to hold the clutch out for a few seconds after it is disengaged, before moving the gear-shift lever to its first-speed position. A quiet gear-shift from neutral to first speed, and also to reverse, can be made only when the transmission gears are almost or

entirely at rest. Sometimes, when trying to engage either first speed or reverse, the gears will not mesh. In such a case, the gear-shift lever should at once be moved to neutral, the clutch should be reengaged and immediately disengaged again, and as soon as the transmission gears are almost at rest the gear-shift lever should be shifted to the desired position.

After the transmission gears have been set for first speed, and the clutch is still held out with the left foot, the engine is speeded up a little either with the hand throttle or with the accelerator; then the clutch is engaged gently and slowly by gradually releasing the pressure on the clutch pedal, when the car will slowly begin to move forwards. The car is then slightly speeded up, the throttle is closed somewhat, the clutch is fully disengaged, and the gear-shift lever is shifted to second speed, the clutch being allowed to engage gently again. As soon as the clutch is fully engaged, the throttle is opened somewhat.

If a four-speed transmission is fitted, the change to third speed is made in the same manner as from first to second speed, as is also the change to fourth speed. In case of a three-speed transmission, the change from second speed to third is also made in the same manner as from first to second speed. It is desirable to run the car, as much as road conditions permit, on the direct drive, which, in case of three-speed transmission, is always the third speed, or *high gear*, and in case of four-speed transmissions may be the third speed or the fourth speed. The spark may now be advanced or retarded to suit the car speed. It is advisable for a beginner to retard the engine with the throttle when shifting from a lower to a higher gear. When running on high gear, slowly, with a wide-open throttle, as in hill climbing, the engine will pull better if the spark is well retarded.

It is bad practice to start a car on anything higher than first speed, especially on an up grade. On a down grade, however, a car can be started safely on second speed, and if the grade is steep enough it may be started on high gear. On an up grade, no attempt should be made to start a car on any higher gear than first speed. To start the car forwards on an up grade, the brakes are not released before the clutch is engaged. First, the clutch pedal is depressed; second, the

gear-shift lever is moved to the first-speed position; third, the engine is speeded up considerably more than is required for starting on a level; and, finally, the clutch is gently engaged while the brakes are gradually released.

To change from a lower to a higher gear on an up grade, the car speed must be somewhat higher than on the level. The movement of the gear-shift lever, as well as the engaging of the clutch, must also be much faster than while running on the level.

The change from a lower to a higher gear on a down grade is made in exactly the same manner as when the car is on the level.

Changing from a higher to a lower gear while running on the level can be done easily. To make the gear-change with a sliding-gear transmission, the throttle is not disturbed; the clutch pedal is simply partly depressed, the gear-shift lever is quickly moved to the lower-speed position, and the clutch pedal is immediately, but gently, released. Changing from a higher to a lower gear on a hill must be done quickly; in fact, it must be done much faster than when making the same gear-change while running slowly on the level.

With a sliding-gear transmission, there is an alternative method of changing from a higher to a lower gear. It requires considerable skill, acquired only by practice, to follow unerringly the steps of this gear-shift, each step of which has to be made very fast. The steps are as follows: Without retarding the engine, depress the clutch pedal just enough to release the clutch; shift the gears to neutral; let the clutch in again; release it once more; move the gears to the lower speed; and, once more, let the clutch in gently. This method of changing from a higher to a lower gear can also be employed to advantage while running slowly on the level if extreme quietness of gear-shifting is required.

A change from a higher to a lower gear on a down grade steep enough to permit the car to coast under its own weight is made only when it is desired to use the engine as a brake. The gear-shift should be made before beginning the descent; if attempting to make the shift after the descent has been begun, the car should be brought first almost to a standstill by use of

the brakes, unless the alternative method of changing from a higher to a lower gear is employed.

In order that a car may be driven backwards, it must first be at a standstill. With the engine running at its lowest speed, the clutch is disengaged, the clutch pedal being depressed far enough to bring the clutch brake into action if one is fitted, or a wait of a few seconds being made if no clutch brake is used, and the gear-shift lever is placed in its reverse position. The engine is now speeded up a little and the clutch gently engaged, when the car will move backwards. Under no consideration should the reverse gear be engaged while the car is moving forwards, because doing so is quite certain to break the teeth of the transmission gears, or *strip the gears*, as it is usually called.

Stopping a Car.—It is the best practice to bring a car to a stop without use of the brakes, if it can be done. To do this, the throttle is closed, the clutch is disengaged, the gears are shifted to neutral, and the clutch is engaged again. The car is then drifting and is rapidly slowing down and will soon stop; the engine, however, still runs at its idling speed. With a little practice the car can be stopped with great accuracy at the place selected. It is good policy, however, to put the right foot on the service-brake pedal, so as to be ready to stop the car with the brakes in case it is seen that the car will run past the desired stopping place.

On a down grade, the car must be brought to a standstill by the use of the brakes; on an up grade, stopping can be done without using the brakes, which must be applied, however, the very instant the car stops so as to prevent it from starting backwards under its own weight. The emergency brakes should always be applied after the car has stopped.

Descending a Hill.—A slight hill may be descended by coasting; to do this, the engine is disengaged from the car by means of the clutch after the throttle has been closed. During the descent either the clutch is held out and the gears are left engaged, or the gears are shifted to neutral and the clutch let in again. The brakes are used, if necessary, to retard the car.

On a steep down grade, the engine can be safely used as a brake, shifting the gears into second or even first speed before

beginning the descent, and closing the throttle. The ignition may be left switched on at first, and cut off later if it becomes advisable; a greater braking effect is secured from the engine if the ignition is cut off.

Stopping the Engine.—All gasoline cars are properly brought to a stop by disengaging the clutch; consequently, the engine remains running. The engine can then be stopped by switching off the ignition. It is advisable to fill the cylinders with a fresh mixture, so as to facilitate starting the engine again; to do this, the engine is speeded up and then the ignition is switched off. Where a dash control or a steering-post control of the carbureter is provided, it is well to adjust this to give a rich mixture before switching off the ignition, thus drawing rich charges into the engine cylinders.

Starting an Engine on a Down Grade.—After a car has been stopped on a steep down grade, the engine may be started as follows: Release the brakes, retard the spark to the usual starting position, set the gear on high or medium speed, close the ignition switch, and open the throttle somewhat. When the car has gained sufficient momentum, gradually let in the clutch, which will start the engine.

Lost or Broken Starting Crank.—When a starting crank has been lost or broken, and no self-starter is fitted, the engine may be started in the same manner as on a down grade. If the car is on the level, it must be pushed forwards, with the transmission set in high gear, until sufficient speed is obtained to warrant letting in the clutch. Never start the engine in this manner unless an experienced driver is in the driver's seat, ready to control the car as soon as the engine is started.

Starting an Engine on Spark.—When the usual form of four-cycle engine with four or more cylinders is stopped, the piston in one of the cylinders is often in position to be started by the impulse of the charge in the cylinder as soon as the charge is ignited and burned. The charge can often be ignited with the spark retarded, by switching on the battery current, and in some dual and double systems, by pushing a button in the battery circuit in addition. Engines fitted only with single magneto ignition cannot be started on the spark.

Under no circumstances should it be attempted to start the engine on the spark unless the spark has been sufficiently retarded to prevent a back-fire. Starting on the spark is somewhat uncertain, as it depends on the engine crank-shaft stopping in such a position that the ignition system will permit a spark to occur in the cylinder on the firing stroke. When the compression in all cylinders is exactly equal, this occurs very frequently, which will explain why new engines will start on the spark more frequently than old engines in which through natural wear compression has become unequal in the different cylinders.

Brakes Failing on a Hill.—Should the service and emergency brakes both fail while descending a hill, brake the car with the engine.

Stoppage of Engine on Up Grade.—Should the engine stop running while ascending a steep hill, apply the brakes immediately, so as to prevent the car from running backwards. If the brakes are out of repair, or if they are not powerful enough to prevent the car from starting backwards, set the change-speed gear in the reverse position at once and turn off the ignition, braking the car with engine.

If no other means of holding the car, such as blocking the wheels with stones, blocks of wood, or running one of the rear wheels against a curb, are available and the engine cannot hold it, the car must be steered backwards down the hill. Every driver should practice driving backwards until he is just as proficient in this as in driving forwards.

Starting a Cold Engine.—If a car has been standing in an unheated garage in winter, it is sometimes difficult to start the engine because the gasoline will not readily vaporize at low temperatures. If priming the cylinders, the intake, or the carbureter, or the use of the strangling valve, fails to help, and no sulphuric ether is available, it is well to refill the cooling system with boiling water. In addition, it is advisable to pour hot water over the intake manifold and the float chamber of the carbureter. Or, a rubber hot-water bag may be filled with hot water and placed in contact with the carbureter.

With cars that are hard to start in winter time, many operators follow the practice of draining the car every time it is

stopped for any length of time, as overnight, in a cold place. In that case, they use only plain water in the cooling system, refilling with plain, hot water every time the engine is to be started.

When stopping the car outdoors for a few hours in freezing weather, it is well, in order to keep the engine warm and hence in good condition for starting, to lay a heavy blanket or automobile robe over the hood and radiator, or to use a radiator cover made for this purpose.

All of the American cars built in recent years are fitted with electric cranking and lighting systems, and hence have electric current available when the engine is not running. This fact has led to the design of electric heaters, placed usually in the intake manifold, by means of which gasoline introduced in the heater from an outside source, usually a small tank carried high up on the forward side of the dash, can be heated and thus vaporized for starting purposes in cold weather. When such an electric heater is fitted, the current is switched on and a little gasoline is introduced in the heater. It is then possible to start the engine in a very short time. When the engine fires regularly, the current must be switched off the heater at once.

Electric heating pads designed to be used with the ordinary 110-volt house lighting current, and which take the place of a hot-water bag, are in the market; their use is naturally limited to garages having electric lights installed.

BRAKES AND CLUTCHES

Brakes.—It is important to have the brakes in perfect order. Brakes should be frequently inspected and tested, especially before making a long trip, to determine whether or not they are in good condition. Care should be taken that the rubbing surfaces of the brakes are not so worn that they cannot be adjusted to hold to their full capacity. Also, when not applied, a brake should not drag, as dragging will cause loss of power and will also heat the brake.

Leather-Faced Cone Clutches.—If the leather of a cone clutch is kept free from oil, it is liable to become glazed so as not to hold well. On the other hand, if oil from the engine or

transmission reaches the leather, the leather becomes uncertain in its action. One of the remedies for a slipping clutch is to tighten the closing spring, or readjust the closing mechanism. Powdered chalk or fuller's earth will temporarily improve the action of a leather-faced clutch if placed between the friction surfaces when the leather is either charred or oily. Either of these substances can be obtained at drug stores. They can be put into the clutch while it is held disengaged either by simply throwing them in or by blowing them in through a piece of tubing. A leather-faced cone clutch should be occasionally washed out with gasoline; when the gasoline has evaporated, some neatsfoot oil should be put on the leather and left to soak in. If the leather facing is charred, it should be replaced.

Multiple-Disk Clutches.—The successful operation of multiple-disk clutches having metal-to-metal friction members depends to a great extent on the kind of lubricant that is used and the thoroughness with which the lubricant reaches all the friction surfaces. The lubricant that seems to give the best satisfaction for most metal-to-metal multidisk friction clutches consists of a mixture of thin lubricating oil and kerosene. Either ordinary machinery oil or gas-engine cylinder oil mixed with kerosene is extensively used. If the lubricant leaks out so as to leave the clutch partly dry, it is almost certain that the clutch will suddenly seize and jerk when closed.

Multiple-disk clutches, in which one set of the disks is faced with a friction lining of the type consisting chiefly of asbestos that is strengthened by a weave of copper or brass wire, are recommended to be run dry by some manufacturers, and to be oiled with a mixture of half kerosene and half cylinder oil by others. The safest thing to do is to follow the recommendation of the maker of the car in any particular instance.

Cork-Insert Clutches.—The use of cork inserts in either a cone clutch or a multidisk clutch gives a smooth action when closing the clutch as long as the inserts are in good condition. The cork is subject to burning and wearing away, especially in heavy service.

CARE OF LIGHTS

Gas Lights.—When refilling the acetylene generator of a motor truck, the holder should not be completely filled,

unless there is a space into which the ash of the carbide can fall. If there is no extra space into which the ash can fall, the carbide receptacle should not be filled more than about two-thirds full. Partly used lump carbide cannot be depended on to produce good gas, when the generator has been standing idle for some time after the charge of carbide is partly used. It is generally advisable to throw away the partly used carbide and to put in a fresh charge.

When filling the water reservoir of the generator, care must be taken that the air vent above the water is open. If the water valve is opened up so as to allow an excess of water to run on the carbide at first, the rapid generation of gas will cause an excessively high pressure in the generator, because the gas cannot escape through the air vent above the water. This, of course, cannot occur in a generator provided with a water seal, which is acted upon in such a manner by an unusually high pressure of gas in a generator as to prevent flow of water on the carbide. The piping should be provided with a small trap at its lowest point into which moisture from the gas may flow, to prevent flickering of the lights.

The tips of the acetylene burners often become clogged with carbon, which can be removed with a piece of fine wire. Burner cleaners can be obtained from all automobile-supply houses, in different sizes to suit the different burners; obviously a cleaner for a $\frac{3}{4}$ -ft. burner must not be used for a $\frac{1}{4}$ -ft. burner, as doing so will break the tip. Acetylene-gas burners are usually marked with the volume of gas they will burn in 1 hr., in fractions of 1 cu. ft.

Oil Lights.—Kerosene is usually burned in the oil lamps. The light should be fully extinguished when leaving the car in the garage. The wicks should be turned down from $\frac{1}{4}$ to $\frac{1}{8}$ in. after the light is out. Turning the wicks down in this manner reduces the amount of kerosene that gradually creeps up.

Electric Lights.—The electric-lighting equipment of cars requires little care. About all there is to do is to see that the lamp bulbs and reflectors are kept clean, and that broken lamp bulbs are promptly replaced with bulbs of the same voltage and candlepower, and same construction of lamp base.

AMERICAN ROAD RULES AND CUSTOMS

Difference in Road Rules.—When driving on the road it should always be borne in mind that each locality has its own laws regulating the movement of vehicles, pedestrians, and other travelers on the highways; also, that in case any of these laws are being violated at the time an accident occurs, the courts will not generally excuse the violator, especially if he is the driver of an automobile that is involved in the accident. While the variation of the laws of different localities is exceedingly great, and some depart radically from the general custom, it is well to know what the general custom is. The following statements may therefore be taken to refer to automobiles only, unless other vehicles or travelers are mentioned.

It should be distinctly understood that the road rules here given are those in general use in the United States of America, where all vehicles keep to the right of the road; in Canada, the rules of the road vary in different localities. In some the American road rules are in common use, while in others all vehicles keep to the left; therefore, when in doubt it is well to apply to the nearest police officer for information, as ignorance of the law is not considered an excuse of its violation.

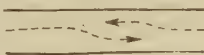


FIG. 2

Passing of Vehicles.—When two vehicles moving in opposite directions approach each other, it is customary for each vehicle to turn to the right in passing, as indicated by the lines with arrowheads in Fig. 2. If two motor vehicles traveling at different speeds are going in the same direction, and the one going at the higher speed wishes to pass the other, it should signal with a horn or other signaling device and then pass to the left of the slower vehicle, as indicated in Fig. 3, where the lines with arrowheads indicate the direction of travel, the speed of

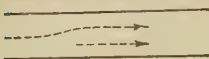


FIG. 3

the vehicle traveling at the fastest rate being indicated by the longer line. If the vehicle going at the slower speed is traveling in the middle of the road or near the left-hand side, it must move to the right-hand side of the road in order to permit the more rapidly moving vehicle to pass. The driver of the vehi-

cle moving at the higher speed should not attempt to pass on the right-hand side of the slowly moving vehicle unless the rear driver knows that the driver ahead is aware of his intention and is willing for him to do so. The slow-moving vehicle always has the right to the right-hand side of the roadway.

Passing of Cross-Streets.—When passing road crossings, the path that must be followed, according to law, is the same as if there were no crossing; that is, the vehicle must be kept

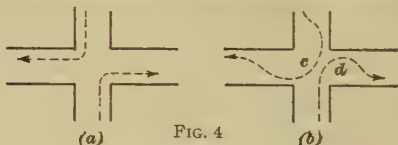


FIG. 4

along the right-hand side of the road. In cities where the streets are crowded with traffic, vehicles moving along the main streets running in certain directions, as those extending north and south, are generally given, by law, the right of way over vehicles passing on less important cross-streets. Therefore, when running on a cross-street, the driver should observe special care to see that the crossing is clear from vehicles and street cars running along the main street. No vehicle should be stopped on any street crosswalk or in any street intersection.

Turning of Corners.—When turning to the right around a corner, the path to be followed is that shown in Fig. 4 (a), and

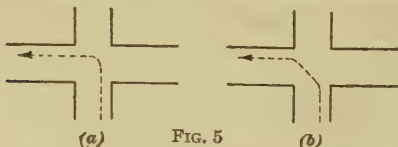


FIG. 5

not that shown in (b). The requirement is that the vehicle shall remain at its own side of the street, which is the right-hand side. When turning to the left from one street to another, the path to be followed is that shown in Fig. 5 (a),

and not that shown in (b). This path must of necessity be followed if the streets are crowded with other vehicles. The vehicle should be driven out nearly straight in its line of travel to at least the middle of the street; then the turn should be made at a rather short radius, so as to bring the vehicle along the right-hand side of the other street.

When a street or a roadway is not crowded it is generally more convenient for the driver of an automobile to violate the rules of traffic, especially when turning corners, than it is to follow them. Thus, a corner can be turned at much higher rate of speed, if, instead of following the path indicated in Fig. 4 (a), the machine is run to the left-hand side of the street before reaching the cross-street, then swung around rather close to the corner, and then run over near to the left-hand curb, as shown at *c*, Fig. 4 (b), thereby following a path of easy curvature. Another easy, but wrong, way is shown at *d* in Fig. 4 (b). It should be remembered, however, that if an accident is caused by deviating from the path of travel, the courts are not inclined to deal gently with the driver that violates the law.

Passing of Street Cars.—When passing street cars that are running slowly or standing to discharge or receive passengers, the general rule is to pass between the car and the right-hand curb, as indicated in Fig. 6. If, when there is a double track, an attempt is made to pass on the left-hand side of the street car, careful ob-

servation should be made to determine whether the roadway is clear on that side. In some localities, the

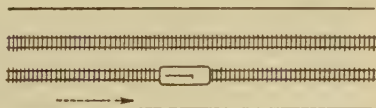


FIG. 6

law forbids a vehicle to pass the left-hand side of a street car, either when there is a double track or only one track in the street. In others, especially with regard to narrow streets, the law forbids a vehicle to pass between a street car and the right-hand curb when the street car is standing to receive or discharge passengers, but it permits passing on the left-hand side of the street car when there is a double track. In some localities,

automobiles are not allowed to pass by the street car at all when it is standing to receive or discharge passengers.

Passing of Animals on Country Roads.—In country districts where the horses or other animals traveling in the roads are likely to become frightened at automobiles, the laws are generally extremely generous to the driver of an animal-drawn vehicle or to a person riding or leading an animal. While at first such a law might seem without basis, there are really very excellent reasons for it. It frequently happens that a team of horses or other animals will pass an automobile when one of the animals is on the side next to the automobile, while the other animal of the team would cause trouble if brought next to the car while passing it. There is also very frequently the condition of the roads to be considered with regard to safety in case of fright of the animals while passing a car, as when one side of the road is precipitous and dangerous, while the other is a wall, bank, or level that is not dangerous.

The law in many rural localities, and in some cities, requires that the driver of an automobile shall stop if the driver of an animal-drawn vehicle signals him to do so, as by holding up one hand. In some cases, this law requires that not only shall the travel of the automobile be stopped, but also its engine, so that there will be an entire absence of noise, motion, and smoke about the car.

SKIDDING

Skidding.—An automobile will skid and slide more easily on paved streets that are only slightly wet, as after a light rain, or sprinkling, than it will on pavement that is thoroughly wetted, as by a heavy rain. This is due to the fact that a dirty, wet pave is much more slippery than a pave that has been washed clean, however wet it may be.

When driving along the sides of an inclined roadway, especially one that is clayey and wet, the speed should be kept very low, for there is danger that the car may slide at any moment to the low side of the roadway. The mud at the side of the roadway is generally softer than at the higher central part, and this has a tendency to throw the car to the side of the road, which will generally result in a serious accident unless the speed of travel is slow or the side of the road is unusually flat.

Either a spinning wheel or a locked wheel will slide more readily than one revolving at a slow speed; hence if the wheels start to skid or slide sidewise, do not put on the brakes so hard as to lock them, nor put on enough power to spin them around, but lower the speed as much as practicable and put on the brakes gradually or intermittently. Imperfectly balanced hub brakes, one gripping quicker or more tightly than the other, are a frequent source of side-slipping, as one locked wheel will nearly always throw the rear end of the car around sidewise. When a car starts to skid, try to steer so as to keep the car parallel with the road. If the roads are slippery, put on the antiskidding chains, unless the wheels have been fitted with antiskid tires, now produced by practically every tire manufacturer.

AUTOMOBILE TROUBLES

STARTING AND RUNNING DIFFICULTIES

Causes of Refusal to Start or of Sudden Stoppage.—The fundamental reasons for an engine refusing to run or of a particular cylinder refusing to work may be summed up as due to no spark, no mixture, or wholly wrong mixture. These cover all the possible causes, which may be enumerated as follows:

(1) Switch not closed; (2) gasoline not turned on; (3) carbureter not primed, or (rarely) primed too much, or flooded; (4) weak battery; (5) gasoline stale or mixed with kerosene; (6) gasoline too cold to vaporize; (7) dirt or waste in carbureter or gasoline pipe; (8) mud splashed into air intake; (9) water in carbureter; (10) soot on the spark plug; (11) water on spark plug; (12) broken spark-plug porcelain; (13) grounded wire (generally secondary); (14) broken wire (generally primary) or loose connection; (15) very bad adjustment of coil tremblers; (16) defective spark coil or condenser; (17) broken circuit-breaker spring; (18) defective high-tension circuit; (19) broken valve stem, spring, or key; (20) valve cams slipped (rare); (21) badly pitted circuit-breaker contacts; (22) improperly adjusted circuit-breaker contacts.

Causes of Irregular Firing or Misfiring.—The principal cause of misfiring is irregular sparking, which may be due to the following causes: (1) Spark plugs defective or covered with soot; (2) weak battery; (3) broken wire, making intermittent contact through vibration of the car (generally found in primary circuit); (4) loose connection at a binding post or anywhere on primary or low-tension circuit; (5) wire occasionally grounded through vibration of the car; (6) with individual transformer coil systems, timer contact surfaces roughened; (7) wobbling or defective timer; (8) poor coil-trembler adjustment; (9) coil trembler sticking at high speeds, due to inertia of heavy armature; (10) insufficient pressure on timer contacts; (11) valve spring weak or broken; (12) sticking, binding, or broken valve, or one badly in need of grinding; (13) particle of carbon under valve; (14) spray nozzle intermittently closed by loose particles of dirt, etc.; (15) air valve of carbureter sticking or binding; (16) mixture too rich or too lean; (17) lubrication excessive or oil not suitable; (18) water in cylinder on account of cracked or porous cylinder, or loose plug in cylinder wall; (19) defective condenser; (20) pitted circuit-breaker contacts.

A sticking inlet valve, which stays open when it ought to close, will cause irregular firing and occasionally back-firing. A very lean or a very rich mixture may be ignitable only by a strong spark. It can always be distinguished from ignition troubles by the fact that the explosion impulses, when they occur, are of much less than normal strength. If the mixture is too rich, there will sometimes be explosions in the exhaust pipe and muffler; if it is too lean, there will ordinarily be back-firing into the carbureter.

A rather uncommon cause of misfiring is a defective condenser; this results in very irregular firing, usually most manifested when the engine is pulling heavily with a wide-open throttle. The most satisfactory test for a suspected defective condenser is to put a new one in place and note results. A fat, bluish spark at the circuit-breaker points, at the instant these break the primary circuit, is a sure indication of a defective condenser; if the condenser is good, a faint, thin, yellowish spark will be observed at the circuit-breaker contacts.

Causes of Weak Explosions.—The causes of the explosions being weak are too lean or too rich a mixture, leakage of compression, mixture diluted with exhaust gases, or spark timing later than it should be, in one or all cylinders. If the trouble is in the mixture, the explosions are regular, unless the mixture is so defective that it sometimes fails to ignite in spite of the spark occurring regularly. The same will be true in any case where, as is usual, the cause of the weakness is unconnected with any irregularity in sparking.

The causes of weak explosions may be enumerated more fully as follows: (1) Dirt or waste in carbureter or gasoline pipe, causing weak mixtures; (2) stale gasoline; (3) air intake partly obstructed, causing rich mixture; (4) bad carbureter adjustment; (5) trouble with float; (6) choked muffler; (7) lack of oil on piston, or oil that is too thin; (8) leak through valve (generally the exhaust valve); (9) leaky spark plugs; (10) valve timing wrong; (11) broken or worn piston rings.

Causes of Failure to Keep Engine Going.—If the engine starts, but soon slows down and finally stops, the trouble may be due to any one or a combination of the following causes: (1) No fuel in tank; (2) fuel does not flow freely to carbureter, the piping being clogged or the vent hole in gasoline tank being closed; (3) broken connection in fuel supply pipe; (4) valve closes suddenly on gasoline supply pipe; (5) water in carbureter; (6) weak battery; (7) defective high-tension circuit; (8) slowing engine down too much before it is properly warmed up.

Causes of Sudden Stoppage of Engine.—If an engine has been running well and stops suddenly, and the cause of the trouble is known not to be due to breakage of an important part, the following causes may be looked for: (1) Fuel tank empty; (2) dirt in carbureter; (3) primary or secondary wire broken or short-circuited; (4) vibrator stuck in a master-vibrator ignition system.

Causes of Back-Firing Into Carbureter.—If explosions occur in the carbureter, the probable causes are: (1) Mixture too lean; (2) inlet valve binds or valve spring is weak; (3) if occurring only when starting the engine, spark is retarded too much.

Causes of Slow But Constant Decrease of Power.—The most probable causes of the power of an engine decreasing slowly

and constantly are the following: (1) Vent closed in fuel-supply tank, provided it is of gravity type; (2) insufficient pressure in compression fuel tank, which may be due to a leaky or binding check-valve in compression pipe, or to the tank not being tightly closed; (3) valve gradually jarred shut in fuel pipe.

Reasons for Failure of Engine to Develop Full Power.—A failure of the engine to develop its full power should not be confused with frictional resistance in the transmission system, or dragging brakes. The chief reasons for this trouble in the engine itself are: (1) Back pressure on account of a choked muffler; opening muffler cut-out or relief valve will at once indicate whether or not this is cause of trouble; (2) lubrication insufficient, especially in cylinder; (3) overheating; (4) compression leaks at valves, around piston, or through a porous cylinder wall; (5) particles of carbon or other dirt under exhaust valves; (6) valves not properly timed; (7) mixture too rich or too lean; (8) ignition spark weak on account of weak battery; the spark does not always occur under this condition; (9) water entering cylinder from water-jacket; (10) defective timing of the ignition, so that it occurs too late or too early.

Reasons for Engine Not Running Slowly and Pulling Car. It sometimes happens that an engine will run at high speed and pull the car, but will fail to pull the car when slowed down. The probable reasons for such behavior are as follows: (1) Carbureter not adjusted properly; (2) magneto magnets weak; (3) compression in the cylinders poor.

Causes of Engine Not Running at High Speed.—If it should be found that an engine will run well at low speeds, but cannot be speeded up to high speed, the probable causes are the following: (1) Carbureter not properly adjusted, or not receiving fuel fast enough; (2) weak battery; (3) vibrator too heavy or set too tight to respond quickly to action of primary current; (4) timer or circuit-breaker defective.

KNOCKING OR POUNDING

Knocks Due to Loose Parts.—Knocking may be due to looseness in some external part. In such cases the cause is readily detected by a careful inspection while the engine is running. This inspection may be aided by laying the hands

on parts suspected of being loose; also by careful scrutiny for evidences of movement where two parts are bolted together. About the most likely place to find looseness of this description is in the holding-down bolts that secure the engine to the frame on which it is mounted.

A prolific cause of knocking is looseness due to wear in the bearings of the main shaft, the crankpin, or the wristpin. Only a very limited amount of looseness should be permitted in the main-shaft bearings of any engine. Looseness in the flywheel bearing of a vertical engine is disclosed by putting a jack or a lever under the flywheel and working it gently up and down. Occasionally, looseness of the shaft can be detected by rocking the flywheel back and forth against the compression in the cylinder. Wear in the crankpin bearings is disclosed by setting the cranks at about half stroke and then rocking the shaft back and forth. Knocking in the wristpin, due to wear of the pin and its bushing, is not among the more common troubles and does not need to be taken care of at once unless aggravated. It is well, however, not to neglect this trouble too long.

Combustion Knocks.—Besides the mechanical causes of knocking, *combustion knocks* may occur without appreciable looseness in the bearings. The usual cause of these knocks is too early ignition, as when running up a hill without suitably retarding the spark. A contributing cause is a slightly weak mixture. Pounding in particular cylinders of a multicylinder engine may be due to unequal rapidity of combustion, which itself may be due to unequal charges, as when the valves are unequally timed, or to irregular spark timing, such as may result from a badly worn timer or timer-distributor or badly adjusted vibrators.

Pounding due to too early ignition is not always due to failure to retard the spark; in fact, a partly compressed charge may often be ignited before the spark occurs by coming into contact with incandescent particles of carbon that adhere to the combustion chamber or piston head. This defective action is called *preignition*. True preignition results almost always, except at the highest engine speeds, in the charge being completely burned before expansion begins, and it is easily distin-

guished, especially if the engine is taking full charges, by the resulting sound, which is a sharp, metallic *bing! bing! bing!* closely resembling that produced by a hammer striking a block of cast iron.

REMOVAL OF CARBON FROM ENGINE CYLINDERS

The soft carbon can be removed quite effectively from the cylinder by means of kerosene. The kerosene should be put in the cylinder when the engine is hot, cranking the engine as many times as it has cylinders and permitting it to stand for some time. If the piston is then worked back and forth or the engine rotated by hand, the soft carbon deposit can generally be washed off completely from the cylinder walls, or it may be blown out through the exhaust if the engine is run a few minutes. It is also sometimes advisable to draw off the lubricating oil from the crank-case and put in a liberal supply of kerosene. Then, after the kerosene has been allowed to stand in the cylinders overnight, the engine should be run for a few minutes, the splashing of the kerosene serving to wash away any carbon particles that would otherwise adhere to the lower ends of pistons and cylinders. The soft carbon will also be at least partly removed from around and under the piston rings.

There are various compounds on the market that, according to claims made for them, will cut the carbon loose rapidly and effectively without injuring the parts of the engine. Some of them remove both hard and soft carbon without apparent injury to the engine.

The hard carbon deposit on the piston head can be removed by scraping. The method of scraping depends, of course, on the construction of the engine. In some forms, a scraper can be inserted through the opening that remains after removing one of the valves. Many engines are so constructed that the cylinder head may be removed without disturbing the piston and valves; in such cases, the part of the cylinder in which carbon deposits occur is readily accessible.

Probably the quickest and most satisfactory way of decarbonizing cylinders, but not the cheapest, is to burn the carbon out by the aid of a fine stream of oxygen introduced into the

cylinders; many garages keep oxygen tanks on hand for this purpose. There is absolutely no danger of damaging the cylinders, pistons, etc., by using the oxygen process.

Cylinders may also be readily decarbonized by using the Michener carbon-removing chain, which is simply a small chain made of copper wire, introduced into the cylinder to be cleaned. The engine is then run slowly for about 10 min. with the spark plug removed from the cylinder containing the chain, which knocks off all the carbon.

COOLING-SYSTEM DIFFICULTIES

Lack of Water in Radiator.—Lack of water in the radiator is indicated by the rapid emission of steam; by overheating and smoking of the engine, followed by laboring, groaning sounds, owing to the oil being burned away, and by seizure of the pistons in the cylinders.

Lack of water is due to carelessness; leakage in the radiator, pump, or piping; accidental opening or breakage of the drain cock. Before refilling the cooling system, allow the engine to cool off. If the pistons have seized, inject a liberal dose of kerosene through the priming cups or spark-plug holes.

Obstructed Circulation.—An obstruction to the circulation elsewhere than in the radiator will cause the bottom of the radiator to remain cool while the top is probably boiling hot. Obstructed circulation may be caused by a broken pump, a broken driving connection to the pump, by waste which has lodged in the pump or piping; or by a piece of hose lining that has become loose and acts as a flap valve or check-valve. Having found the cause by inspection, the remedy is obvious in each case.

Fan Troubles.—A simple trouble likely to be mistaken for radiator or circulation trouble is the slipping of the fan belt. If the fan does not run at full speed, the cooling water may become so hot as to allow the cylinders to overheat. Nearly all modern cars at present, when using a belt-driven fan make the fan bracket adjustable, which permits the proper belt tension to be maintained. If the belt has lengthened beyond the range of adjustment of the fan bracket, it must be shortened or a new one provided. In an emergency, as when

the fan belt is lost, the fan may be driven temporarily by means of either a strong piece of cord or a piece of belt lacing.

When fans are gear-driven, as is often the case, any failure of the fan to run can easily be traced home, as it is due either to the working loose of a fastening device or to a broken gear.

Scale or Sediment in Radiator.—The presence of scale or sediment in a radiator is indicated when the whole radiator becomes unusually hot. Overheating of the radiator because of scale should not be confused with that due to a large decrease in the radiation of heat because the outside of the radiator is covered with an excessive amount of dirt or mud, nor with that due to the production of an unusual amount of heat in the engine.

Soft mud can be washed out by attaching a hose to the cooling system and forcing water through it as rapidly as possible. The water should be sent through first in one direction and then in the other. Mud on the outside of the radiator can be removed by means of water or water and soap, and for the removal of external oil and dirt, gasoline applied with a brush or a swab will be found effective. Remember that gasoline vapor is highly inflammable.

The scale deposited by the hard water that is found throughout a considerable portion of the United States can be softened and removed with a solution of common washing soda. The proportions of the solution are about 2 lb. of soda crystals to 1 gal. of water. Before putting in the solution, the system should be thoroughly drained. The water drained out should be measured, and then an equal quantity of the solution made up and put into the cooling system so as to fill it. The solution can be left for 8 or 10 hr. and drawn off, after which the system should be washed until the water that flows from it is clear. The scale is loosened by the soda and washes out in the form of sludge, which looks like mud.

Defective Pump Packing.—If the packing of the cooling-water circulating pump becomes loose enough to cause a leak, the water system will be gradually drained. When the water level falls below that necessary to keep up circulation, the cylinders will become hot, possibly hot enough to cause trouble in the engine. The obvious remedy is to tighten up the stuff-

ingbox, or to repack the pump if this fails. For repacking the pump, either use packing supplied by the manufacturer, or regular flax water-pump packing such as can be obtained in any engineers' supply store.

LUBRICATION TROUBLES

Lack of Oil.—The symptoms of lack of oil are manifested in a sudden laboring of the engine, a dry or groaning sound, and partial loss of compression, followed probably by seizing of the pistons. Among the causes of lack of oil are clogging of oil pumps by dirt or waste, obstruction in oil pipes, leaky check-valves, leaky pump packing, broken oil pipes, oil too cold to feed, lack of oil in crank-case, etc. The remedies for trouble due to lack of oil will become obvious on inspection.

Because the main bearings, wristpins, crankpins, and all the smaller bearings within the crank-case are lubricated from the same system that supplies oil to the cylinders, any lack of oil in the system will hurt these bearings. If the bearings are Babbitt-lined, the Babbitt may be melted out. With the more modern lubrication systems used for automobile engines, trouble is almost invariably due to failure to replenish the oil supply in the reservoir whence it is drawn. Too rapid an exhaustion of the oil supply may be and often is due to a defective crank-case gasket, or to a drain cock left partly open.

Improper Oil.—The trouble symptoms produced by the use of oil unsuited for lubricating the piston are white or yellow smoke in the exhaust, rapid fouling of the spark plugs, and rapid accumulation of carbon on the valves in the combustion chamber and about the piston rings.

To remedy the trouble, empty out all the unsuitable oil, if possible, and substitute oil known to be good. Before good oil is supplied, it is advisable to thoroughly wash out the crank-case with kerosene; after the poor oil has been drained, put in from 3 to 4 qt. of kerosene and run the engine for 1 or 2 min. Then drain the crank-case again, and refill the lubrication system with fresh oil. If there is much carbon in the combustion chambers, on the pistons, and on the valves, it should be removed. As good automobile-engine oils are obtainable almost anywhere, there is little excuse for the use of improper

oil. Under no circumstances should steam-engine cylinder oil be used; always use gas-engine oil.

Too Much Oil on Pistons.—Too much oil on the pistons is indicated by white smoke on the exhaust and fouled spark plugs, substantially as when inferior oil is used, though the symptoms are not so pronounced. An examination of the combustion chamber will show an unnecessary amount of oil around the top of the piston. Trouble from this source is remedied by drawing off part of the oil from the crank-case, and reducing the oil feed if this is possible.

CYLINDER AND PISTON TROUBLES

Scored and Leaky Cylinders.—One cause of scoring of the cylinder lies in the fact that the ends of the piston pin or wrist-pin, when loose, sometimes protrude through the hole, or bearing, in the piston. There are several other causes, however, aside from lack of oil, that may cause scoring; these are dirt in the oil, poorly fitted or broken piston rings, and loosening of the pins that are sometimes used to prevent piston rings from turning. Particles of sand may also be drawn in through the carbureter. If, in an engine in which the inlet and exhaust valves are tight and there is no leaky gasket, the compression has become materially reduced, the trouble is probably caused by leaks from distorted, scored, or imperfect cylinders, the pistons or piston rings being worn considerably, or stuck in the slots of the piston. If the cylinder is found to be out of round or scored, it must be rebored or reground and new pistons and rings must be fitted unless a new cylinder and piston can be obtained at a lower cost.

There are a number of concerns specializing on filling the scores in a cylinder by a silver composition, permitting the same pistons to be used after the cylinder is repaired. The process used is a patented one, and hence it is not open to use by the public.

Cracked Cylinders.—The result of overheating, due to the failure of the cooling system, as well as of the freezing of the water in the jacket, is a cracked cylinder. An engine that has a cracked or porous cylinder wall will always heat the cooling water more rapidly than when there is no such defect. Some of the cooling water will generally be drawn into the cracked

cylinder during the suction stroke. This water immediately vaporizes, and the steam thus formed prevents a full charge from being drawn in during the suction stroke.

About the only really satisfactory way of permanently repairing a cracked cylinder is to have it welded by the oxy-acetylene autogenous welding process.

Cylinder-Head Packing Troubles.—When cylinder heads are made removable, the joint between them and the cylinders is made tight by means of a gasket. This may be of sheet copper and sheet asbestos, made at the factory to the correct shape, or, in the absence of a regular copper-asbestos gasket, ordinary wire-woven asbestos packing, which is about $\frac{1}{2}$ in. thick. If the joint leaks, it is usually due to uneven tightening, or insufficient tightening, of the cylinder-head bolts, and the remedy is obvious. If a gasket made from wire-woven asbestos packing leaks, it will usually have to be replaced with a new one if tightening the bolts does not stop the leak. A copper-asbestos gasket will stand being used quite a number of times; it should be annealed, however, before it is used again. The surfaces between which the gasket is placed should be very carefully cleaned.

Worn Pistons.—When pistons show an undue amount of wear, either on their cylindrical surface or in the wristpin holes, it is usually much cheaper and more satisfactory to replace the worn piston with a new one than to attempt to repair the old one.

Stuck, Worn, and Broken Piston Rings.—Piston rings become stuck in their grooves from rusting, which is extremely uncommon if the car is regularly used; or from carbon deposits, which is the most common cause; or from the sides of the slot being slightly tapered, which is uncommon. Piston rings that are rusted fast or stuck from carbonized oil may be loosened by soaking the piston in kerosene and then working the rings back and forth. Badly worn as well as broken piston rings should be promptly replaced.

VALVE TROUBLES

Leaky Valves.—Valves will become leaky because of warping and pitting, especially the exhaust valves, unless made

from a high-grade tungsten steel; they should be promptly ground to their seats, using one of the many grinding pastes that are on the market for this purpose. Leaky valves manifest themselves through loss of compression. It will be understood that a bit of dirt or other foreign substance caught between the valve and its seat will also cause lack of compression.

A bent valve stem may cause the valve to leak by preventing it from seating properly. Such a stem may also bind in its guide, so that the valve remains quite wide open at times but closes more or less perfectly at other times. A new valve is the best remedy.

A valve stem that is too long will also cause a valve to leak. After regrinding a valve, the stem may be so long as to strike its push rod or lifter so that the valve cannot rest on its seat. A stem that is just long enough to allow the valve to seat itself when the engine is cold may be expanded enough by the heat when the engine is running to prevent the valve from settling on its seat. The remedy is to readjust the valve stem or valve lifter.

A dirt-coated valve stem may cause the valve to behave in much the same manner as a bent stem. A dirt-coated valve stem can sometimes be cleaned by putting kerosene on it while the engine is hot.

Broken Valve Stem or Key.—Trouble from broken valve stems or keys manifests itself by loss of power and clattering of the valve on its seat, because the valve spring then does not seat the valve. The remedy is a new valve or a new key, depending on which of the two is broken.

Broken Valve Spring.—The symptoms of broken valve springs are identical with those accompanying broken valve stems or keys. The best remedy is a new spring. A broken valve spring of the coiled-wire type can sometimes be temporarily repaired by placing a metal washer, such as is used on bolts, between the two ends of the broken spring.

MUFFLER AND EXHAUST-PIPE TROUBLES

Feeding an overrich mixture to the engine for some time will clog the muffler with loose carbon, which will reduce the power

of the engine by creating an abnormal back pressure. The remedies are to readjust the carbureter to give a proper mixture and to clean out the muffler.

A very hot exhaust pipe may be due to a clogged muffler or to the ignition being too late in one or all of the cylinders. If the ignition is not synchronous, it should be brought into synchronism, so that there will be no reason for late ignition in any of the cylinders.

FUEL-SUPPLY TROUBLES

Symptoms of Fuel Exhaustion.—When the fuel supply in the fuel tank becomes low, the engine will uniformly, but quite rapidly, lose power and stop. The length of time required for this to occur depends of course on how much power the engine is called on to develop at the time. Many modern gasoline tanks are fitted with a small compartment in which gasoline is kept in reserve. Communication between the main and reserve compartment is ordinarily closed. However, on the fuel in the main compartment giving out, the reserve compartment can be readily brought into action.

Effect of a Clogged Vent Hole.—If the vent in a gravity fuel tank is clogged and the tank otherwise tightly closed, the engine may lose power very gradually and finally stop. The length of time required to bring the engine to a stop depends on the amount of air space above the gasoline in the tank. The remedy is to open the vent, which will usually be found in the center of the filler cap.

Effect of Water in Gasoline.—If the fuel is always poured through a strainer, troubles from water will rarely be encountered. However, should water get into the fuel tank, it will almost immediately stop the engine when it reaches the carbureter. If only a few drops of water are drawn through the spray nozzle at a time, the engine may not be stopped, because the momentum of the moving parts may be sufficient to keep it running. Its failure to develop power while receiving water from the carbureter, however, is very evident. The remedy is to drain the tank and carbureter. Many modern tanks have a settling chamber at the bottom with a drain cock attached thereto; emptying this settling chamber will usually be sufficient to get rid of the water that reached the fuel tank.

TROUBLES FROM LOOSE OR BROKEN PARTS

Broken or Missing Part Between Engine and Driving Wheels.—If the engine runs but will not drive the car, some part of the power transmission system is either broken or lost; a systematic investigation will usually disclose the trouble.

Loose Bearings.—If a connecting-rod or a crank-shaft bearing is very loose, it will invariably give rise to knocking or pounding. A ball bearing that has become worn more than is allowable in good practice will generally pound or knock, but the sound is ordinarily not so sharp as in the case of plain bearings.

Loose Fastening Devices.—A loose bolt or other similar device used to fasten the engine to the frame of the car or even to fasten parts of the car frame together will sometimes cause a loud knocking noise that may very easily be mistaken for a loose bearing in the engine or other parts of the car. The car should therefore be examined for such loose parts.

CARBURETER TROUBLES

Overrich Mixture.—If a mixture is very rich, black smoke will appear in the exhaust. If the mixture is too rich, but not rich enough to produce smoke, it will produce a pungent, acid odor in the exhaust, and will cause overheating of the radiator, unnecessary sooting of the plugs, accumulation of carbon in the combustion chamber, and unnecessarily rapid consumption of gasoline, with diminished power.

The causes of an overrich mixture are faulty carbureter adjustment, leaky float, leaky float valve, float too high on its stem or too heavy, spray nozzle loosened or unscrewed by vibration, and an obstructed air-intake pipe, mud usually having splashed into it. If the level of gasoline in the float chamber of a carbureter is too high, the carbureter is said to be *flooded*. The result of a flooded carbureter is a mixture too rich in gasoline.

Weak Mixture.—Among the symptoms of trouble produced by a weak mixture are insufficient development of power, although the explosions may be regular, and a tendency to preignite; also, the engine sometimes will miss every other explosion, and there is likely to be difficulty in starting the

engine. It is not always easy to distinguish between lack of power due to an overrich mixture and that due to a weak mixture. However, the tendency of the former is to produce black smoke and explode in the muffler, and that of the latter is to preignite, and cause back-firing into the carbureter, as well as misfiring.

A leak in an inlet pipe allows air to be drawn into the mixture. If the leak is in a branch that leads to one cylinder only, that cylinder will receive a weak mixture. If the air leak is large, the dilution of the mixture for the one cylinder will be sufficient to cause misfiring and possibly back-firing into the carbureter, although the latter is properly adjusted for the remaining cylinders.

It is generally not difficult to discover a large leak in an inlet pipe. By holding the hand around the pipe where a leak is suspected, the current of ingoing air can be felt. However, if the leak is small, a liberal supply of cylinder oil placed around the joint will generally indicate a leak, because the oil will be drawn into the pipe. The remedy for a leak in an inlet pipe is to repack or otherwise refit the leaky joint.

Dirt in the Carbureter.—If there is dirt on the float valve, it will cause the carbureter to flood. Flooding is highly dangerous on account of the liability of fire. If dirt is in the spray nozzle, it will produce a weak mixture. If the dirt has been splashed into the air intake, it will produce an overrich mixture, especially at high speeds. The remedies for trouble due to dirt in the carbureter will become obvious when the nature of the trouble is located.

Dirt in Gasoline Pipe.—The symptom of a gasoline pipe becoming obstructed is a sudden or gradual weakening of the mixture, which may lead to a sudden stopping of the engine. If the engine will start promptly after standing a few minutes, run well for a little time, and then stop again, it is almost always due to an obstruction to the flow of gasoline, either in the pipe or in the carbureter passages. An obstruction in the gasoline pipe can usually be dislodged, the pipe having been removed from the car, by blowing through it with a tire pump. If there is a strainer between the tank and the carbureter, the strainer may have become clogged and hence should be taken

apart and cleaned. To test the gasoline pipe, close the cock at the tank, disconnect the pipe from the carbureter, and open the cock again; if a full flow of gasoline comes from the end of the pipe, it is clear.

Leaky Float Valve.—With a leaky float valve, the carbureter drips gasoline. The leakage is not stopped by a priming that would remove a small particle of dirt on the float-valve seat or in the spray nozzle. The trouble may be remedied, however, by grinding the valve to its seat.

Leaky Float.—If a metallic float has become leaky and its buoyancy has thus been destroyed, the float valve will be held away from its seat and the carbureter will be flooded continually, as in the case of a leaky float valve. The obvious remedy is to either repair the leak by soldering, or to put in a new float, just as may be considered most expedient.

A cork float that has become saturated with gasoline, or *loggy*, should first of all be thoroughly dried. It may then be varnished with shellac varnish, letting the shellac dry for 24 hr.

Float Too High.—When the float is too high in its chamber, it is not lifted by the gasoline sufficiently to close the float valve before gasoline escapes from the spray nozzle. If this trouble is present, the carbureter drips gasoline. The obvious remedy is to lower the float, say $\frac{1}{8}$ in., and more if this is not sufficient.

Float Too Heavy.—The same symptoms are present when the float is too heavy as when the float is too high, but they are caused generally by a leak in the float or by a float that is gasoline-soaked.

Effect of Cold Carbureter.—When the engine is first started in cold weather, liquid gasoline is quite likely to drip from the carbureter until this as well as the intake manifold has become heated from continued running of the engine. This will be the case even though a preheated air supply for the carbureter is provided. The reason for this lies in the present-day heavy gasoline, only the lighter constituents of which vaporize at low temperatures. The heavier constituents collect in the manifold and run out of it until it has become hot enough to vaporize them. This trouble cannot be cured readily, but must be endured. If means are at hand for heating the

carbureter and intake manifold before starting the engine, little trouble will be experienced from the cause mentioned.

Back-Firing Into Carbureter.—The cause of back-firing through the inlet valve is generally a delayed combustion of a weak mixture. The result of such a mixture is a weak explosion and slow burning. The fresh charge will, therefore, be ignited by the flame of the previous charge; and, as the inlet valve at that time is open toward the air-supply pipe or passage, an explosion will occur in either the intake pipes or the carbureter. The remedy is to increase the fuel supply or to decrease the air supply. Explosions in the carbureter may also be caused by an inlet valve failing to close, thus permitting the mixture burning in the cylinder to ignite that in the inlet pipes and the carbureter.

Back-firing into the carbureter when starting a cold engine is not necessarily an indication of an ill-adjusted carbureter, but may be, and often is, due to the spark being retarded too much; a little experimenting with advancing the spark more for starting will quickly show if a retarded spark is the cause.

IGNITION TROUBLES

Battery Troubles.—In practically all modern automobiles, ignition is normally effected either by a magneto or by a dynamo-and-storage-battery ignition system with a timer-distributor and a single non-vibrating induction coil. Single ignition is now the rule; dual ignition is usually found only on cars with low-tension magnetos, and double ignition is very rarely met with. Practically the only car built at present with individual vibrator coils and a timer is the Model T Ford, which uses a low-tension high-frequency alternating-current magneto as a source of current, and has the ignition system arranged so that dry cells (or a storage battery) may be used as an auxiliary current source.

With a dual system, ignition troubles occurring only when the battery is used as a current source are almost invariably due to an exhausted battery, and hence this should be tested at once. In case of dry cells, each should be tested separately with an ammeter connected across the two terminals of the cell; if the cell shows less than 10 amp., it is practically worth-

less for ignition purposes. A storage battery may be tested with a voltmeter (an ammeter as used for testing dry cells will promptly burn out when applied to a storage battery), and if the voltage is less than 5 volts, may be considered as dead and in need of recharging, repairs, or replacement; it is well to test the storage battery when ignition trouble develops in a dynamo-and-storage-battery ignition system. Instead of making a voltmeter test, which can be relied upon only in case it is made while the storage battery is discharging, a hydrometer test may be made; if the specific gravity falls below 1.15, the battery is practically discharged.

Dry cells that have become exhausted can often be made to give current for a short time by pouring through holes punched into the sealing paste at the top as much water, cider vinegar, or muriatic acid as the cell will absorb. The best results will be obtained from the use of muriatic acid, in the handling of which great care must be taken; cider vinegar is next in efficiency, and water is the least efficient.

Spark-Plug Troubles.—Spark plugs, generally speaking, give trouble from soot or oil on the insulation forming a short circuit for the high-tension current, from broken porcelains, and from spark points wrongly spaced. Spark plugs can be cleaned of soot or oil by a stiff bristle brush and gasoline, and must be taken apart if necessary. If a broken or cracked porcelain is found, it should be replaced with a new one, or a new spark plug obtained. The spark points should be not less than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. apart; many makers of magnetos recommend $\frac{1}{8}$ in.

With the modern dynamo-and-storage-battery ignition systems a distance of $\frac{1}{32}$ in. between spark points will usually give good results; when closed in to $\frac{1}{8}$ in. or less, the ignition will usually be poor, often manifesting itself by very irregular running of the engine when idling.

A leak between the plug shell and the cylinder will be denoted by the hiss of escaping gas on the compression and power strokes. In such cases, the plug may be screwed tighter or a new gasket used. If the leak is through or past the packing inside the plug, the same hiss will be heard, and, in addition, the outer end of the porcelain will show traces of soot after

the gases have been leaking for some time. If the plug bushing has been screwed as tight as is prudent, with regard to the safety of the porcelain, it will be necessary to repack the plug.

Induction-Coil Troubles.—If the vibrator of an induction coil does not work freely, the symptom will be erratic firing. Too light a pressure of the contact screw will cause the engine to run weakly and fitfully; too much pressure will exhaust the battery rapidly. Poor firing may be caused also by pitting of the contact points. This trouble may be remedied by filing the contact points and readjusting the spring and contact screw.

A condenser that is short-circuited or has one of the connections broken will show it by excessive sparking at the trembler and timer contacts, and by rapid burning of the metal where the primary-current spark occurs. If the condenser forms distinctly a part of the induction coil, this will have to be returned to the factory for repair or replacement. In many of the modern ignition systems the condenser forms a separate unit, and hence is easily replaced by a new one. Owing to the low cost of an entire new condenser, repairs of a damaged one are rarely attempted, even at the factory where made.

An induction coil may short-circuit from breakdown of the insulation in either the primary or the secondary winding. The symptoms of this trouble are a poor spark or none at all, and, in case of a vibrator coil, refusal of the vibrator to work, even with a good source of current supply. The only remedy is to send the coil to the factory for repairs.

Break in Primary Circuit.—The symptoms produced by a break in the primary circuit are intermittent sparking or complete failure to spark. The almost invariable cause of breaks in the primary circuit is vibration. The first step to be taken in remedying the troubles is to test every binding post. If this does not disclose the trouble, hunt for a break in the wiring. It will generally be found close to a binding post, switch terminal, or other connection. If the wire has a soldered joint, it may be brittle at that joint and may have broken; or, it may have been fastened in such a manner as to strain it; or a badly made and twisted joint may have worked loose. Note that the break may be between the timer and

the coil, in which case it will affect only one coil. A wire is quite likely to break inside its insulation, or just at the point where the insulation has been stripped off. Occasionally a break is found in the primary winding of the induction coil; this may be tested for by means of a battery and bell.

Short Circuit, or Ground, in Primary.—A short circuit, or ground, in the primary conductor is not a common trouble. The symptoms of such trouble are much like those due to a broken wire, but an ammeter test close to the battery will show that current is flowing.

Broken Secondary Cable.—As the secondary cables are short and thick, a break in them is an unusual occurrence. If the break is not too great, the current will jump it, and the sparking there will at once disclose the trouble.

Grounded Secondary Cable.—A grounded secondary cable, which is indicated by failure to spark, is generally due to the chafing through of insulation on a badly supported cable. Sometimes it is due to rotting of rubber insulation by heat and oil. The roadside remedy for a grounded secondary wire is to tie the cable clear of the metal work. The permanent remedy is to put in a fresh cable that is adequately protected by fiber tubes or other insulating supports.

Dirty Circuit-Breaker Contacts.—In either a magneto or a timer-distributor, any dirt, such as oil or a speck of dust, between the contacts will hold the contacts apart and hence leave the primary circuit open, thus stopping the working of the ignition system. The remedy is to clean the contacts.

Timer Contacts Roughened by Wear.—Trouble due to roughening of the timer contacts, a timer being used only with individual coil systems, is likely to occur in any timer in which the contact segments are inserted flush with the insulator barrel or internal ring. The symptom produced by roughened contacts is irregular firing. The remedy is to true the insulator ring and segments in a lathe and put in a new roller, or to put in an entire new timer, depending on which is the cheaper.

Wabbling Timer.—Some timers have their stationary portion supported on the shaft by a very short bearing that quickly wears loose and allows the stationary portion to wobble

out of its correct plane; this will cause irregular firing or even misfiring. Replacing the stationary part, or bushing the worn hole, will remedy the trouble.

Testing Spark Plugs.—Where an engine is fitted with a dual ignition system, a double ignition system, or only with a battery system, the spark plugs can be tested readily with the aid of the battery without running the engine. Remove all spark plugs from the cylinders, and, with the secondary wires attached to them, lay them on the engine so that the spark-plug shells touch the metal of the cylinders. Complete the primary circuit by closing the switch on the battery system and slowly turn the engine over by hand, watching for the spark at the spark gaps of the several plugs. If any plug fails to spark, it may be due to a faulty plug or to a fault in the ignition system for that plug; to see if it is the latter disconnect the secondary wire from the suspected plug and hold it so that the terminal of the wire is about $\frac{1}{8}$ in. from the engine. If on turning the engine over a spark jumps the gap between the secondary wire and engine, the high-tension current reaches the spark plug, but as the plug does not spark, it is bad. Before making any test for a defective spark plug, it is advisable to make sure, in the manner just explained, that the high-tension current reaches each spark-plug terminal.

When vibrator coils and a timer are used on a dual system, the plugs may be tested on the battery system without turning the engine over to complete the primary circuit for each plug. Turn the engine until no vibrator works; then short-circuit, with a screwdriver, in succession from each timer terminal to the engine, which will complete the primary circuit for each cylinder.

With individual vibrator coils and a low-tension magneto or a battery discharging into them, and the engine running, the spark plugs may be tested and a defective one found by depressing a pair of vibrators at a time and noting how the running of the engine is affected.

If the engine is fitted only with high-tension magneto ignition, the defective spark plug may be found as follows, with the engine running: Take out spark plug of cylinder 1 and screw a new plug in place. Run engine and note if missing still continues; if it does, the old spark plug of cylinder 1

was all right. Remove the new spark plug to cylinder 2 and replace the old spark plug in cylinder 1, start the engine and note results. Continue in this way until the bad spark plug, which is the last one removed before the missing was stopped, has been found. Another way is to short-circuit each spark plug with a screwdriver or a piece of secondary wire, bridging from the spark-plug terminal to the engine. The plug that does not affect the running of the engine when short-circuited, is defective.

USEFUL INFORMATION

DIGEST OF AUTOMOBILE LAWS BY STATES

OFFICIALS ENFORCING AUTOMOBILE LAWS

When compiling the digest of automobile laws, every effort has been made to bring them up to date at the time of publication. However, on account of the rapid growth of the industry and the new conditions that are constantly arising, new provisions are being made by the different states from time to time, so that, in case an important point is to be decided, where there is reason to think that a change might have been made in that particular law, it is always best to obtain a copy of the most recent legislation. The following authorities have been consulted in making the digest: The Automobile, The Horseless Age, and Chilton's Automobile Trade Directory. Complete information may be secured regarding state automobile laws by writing to the following officials for the laws of their respective states:

Alabama, Secretary of State, Montgomery, Ala.

Arizona, Secretary of State, Phoenix, Ariz.

Arkansas, Sheriff of County.

California, Motor Vehicle Department, State Treasurer, Sacramento, Calif.

Colorado, Secretary of State, Denver, Colo.

Connecticut, Secretary of State, Hartford, Conn.

Delaware, Secretary of State, Dover, Del.

District of Columbia, Secretary of Automobile Board, Washington, D. C.

Florida, County Tax Collector.

Georgia, Secretary of State, Atlanta, Ga.

Idaho, Secretary of Highway Commission, Boise City, Idaho.

Illinois, Secretary of State, Springfield, Ill.

Indiana, Secretary of State, Indianapolis, Ind.

Iowa, Secretary of State, Des Moines, Iowa

Kansas, County Treasurer.

Kentucky, Secretary of State, Frankfort, Ky.

Louisiana, Secretary of State, Baton Rouge, La.

Maine, Secretary of State, Augusta, Me.

Maryland, Commissioner of Motor Vehicles, Baltimore, Md.

Massachusetts, State Highway Commission, Boston, Mass.

Michigan, Secretary of State, Lansing, Mich.

Minnesota, Secretary of State, St. Paul, Minn.

Mississippi, State Auditor, Jackson, Miss.

Missouri, Secretary of State, Jefferson City, Mo.

Montana, Secretary of State, Helena, Mont.

Nebraska, Secretary of State, Lincoln, Neb.

Nevada, Secretary of State, Carson City, Nev.

New Hampshire, Secretary of State, Concord, N. H.

New Jersey, Commissioner of Motor Vehicles, Trenton, N. J.

New Mexico, Secretary of State, Santa Fe, N. Mex.

New York, Secretary of State, Albany, New York, Buffalo

North Carolina, Secretary of State, Raleigh, N. C.

North Dakota, Secretary of State, Bismarck, N. Dak.

Ohio, Secretary of State, Columbus, Ohio

Oklahoma, Department of Highways, Oklahoma City, Okla.

Oregon, Secretary of State, Salem, Ore.

Pennsylvania, State Highway Department, Harrisburg, Pa.

Rhode Island, Board of Public Roads, Providence, R. I.

South Carolina, Clerks of Courts of Counties.

South Dakota, County Treasurer

Tennessee, Secretary of State, Nashville, Tenn.

Texas, County Clerks.

Utah, Secretary of State, Salt Lake City, Utah

Vermont, Secretary of State, Montpelier, Vt.

Virginia, Secretary of Commonwealth, Richmond, Va.

Washington, Secretary of State, Olympia, Wash.
West Virginia, State Auditor, Charleston, W. Va.
Wisconsin, Secretary of State, Madison, Wis.
Wyoming, Secretary of State, Cheyenne, Wyo.

ALABAMA

Registration.—With the Secretary of State; fee, \$7.50 under 20 H. P.; 20 to 29 H. P., \$12.50; 30 to 39 H. P., \$17.50; over 40 H. P., \$20; electric vehicles, \$12.50; steam vehicles, \$15; motorcycles, \$3; commercial cars, \$25; manufacturers, garages, and dealers, \$100. Chauffeur's license, \$5, annual renewal, \$2.50; application must have written indorsement of three registered motor-vehicle owners in county in which application is made.

Speed.—Reasonable and proper, having regard to local conditions. Not over 30 mi. per hr. in $\frac{1}{2}$ mi.

Non-Residents.—Reciprocal exemption.

ARIZONA

Registration.—With Secretary of State, fee, \$5 for an automobile up to 25 H. P., \$10 up to 39 H. P., and \$15 for 40 H. P. and over, S. A. E. rating; motorcycle fee, \$2. Registration of car in case of sale, \$3; chauffeur's license, \$5. Must display two white lights in front and one red light in rear.

Speed.—Reasonable and proper; in built-up sections 10 mi. per hr.; elsewhere in city limits, 15 mi. per hr.; outside municipalities, 30 mi. per hr.

Non-Residents.—Exempt 6 mo. with home tags.

ARKANSAS

Registration.—With the Secretary of State, annually; fee, \$5. Dealers must register one car of each class in which they deal, cars being classified as electric, steam, or gasoline. Transfer fee in case of purchase of registered car, 50c. Chauffeurs must register annually, fee, \$1.

Speed.—Reasonable and proper; in business section, 8 mi. per hr.; outside of municipalities, 20 mi. per hr.; while rounding or approaching corners or dangerous crossings, 6 mi. per hr.

Non-Residents.—License tags of home state must be carried.

CALIFORNIA

Registration.—Annually, with Motor Vehicle Department, State Treasurer. Fee, 40 c. per H. P.; electrics, \$5. Registration between April 1 and June 30, three-quarter fee; between July 1 and September 30, one-half fee; between October 1 and December 31, one-quarter fee. Chauffeur's license, \$2.

Speed.—Reasonable and proper; in business districts, 15 mi. per hr.; in built-up sections, 20 mi. per hr.; on curves, etc., 10 mi. per hr.; elsewhere, 30 mi. per hr.

Non-Residents.—Exempt for 3 mo. with home tags.

COLORADO

Registration.—Annually, with Secretary of State; up to 20 H. P., \$2.50; up to 39 H. P., \$5; over 40 H. P., \$10. Chauffeur's license, \$1; motorcycles, \$2. Must display at night two white lights forwards and one red light at rear.

Speed.—Reasonable and proper.

Non-Residents.—Exempt for 90 da. with home tags.

CONNECTICUT

Registration.—Annually, with Secretary of State; 50 c. per H. P.; motorcycles, \$2; owner's and chauffeur's driving license, \$2. Must carry two white lights forwards and one red light at rear.

Speed.—Reasonable and proper; 25 mi. per hr. for $\frac{1}{2}$ mi. maximum; reduce to 10 mi. per hr. on curves, etc.; stop 10 ft. back of street car receiving or discharging passengers.

Non-Residents.—Reciprocal exemption.

DELAWARE

Registration.—Annually, with Secretary of State; fee, \$5. Family license, enabling any member of the owner's immediate family to drive, \$8; chauffeur's license, \$5.

Speed.—Reasonable and proper. In built-up sections, 15 mi. per hr.; on curves, etc., $7\frac{1}{2}$ mi. per hr.; passing vehicles, curves, etc., in thinly settled sections, 12 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Reciprocal exemption.

DISTRICT OF COLUMBIA

Registration.—Perpetual, with Secretary of Automobile Board; fee, \$2. Owner's and chauffeur's driving license, \$2, perpetual.

Speed.—Within fire-limits, 12 mi. per hr.; in parks, 15 mi. per hr.; 8 mi. per hr. at street intersections; 6 mi. per hr. around corners; 4 mi. per hr. at street-car intersections; outside of fire limits, 20 mi. per hr.; 12 mi. per hr. when meeting or passing other vehicles; must stop back of street cars receiving or discharging passengers.

Non-Residents.—Reciprocal exemption

FLORIDA

Registration.—Perpetual, with Secretary of State; fee, \$2. Chauffeur's license, \$2.

Speed.—Reasonable and proper. On curves, etc., 4 mi. per hr.

Non-Residents.—Exempt for 30 da. with home tags and reciprocity.

GEORGIA

Registration.—Annually, with Secretary of State; fee, \$5. No chauffeur's license.

Speed.—Reasonable and proper. On curves, etc., 6 mi. per hr.

Non-Residents.—Exempt 30 da. with home tags.

IDAHO

Registration.—Annually, with Secretary of State through County Assessors; fees, to 30 H. P., \$15; to 40 H. P., \$20; to 50 H. P., \$25; over 50 H. P., \$40. Chauffeur's license, \$2.

Speed.—Careful and prudent, not over 30 mi. per hr.

Non-Residents.—Reciprocal exemption.

ILLINOIS

Registration.—Annually, with Secretary of State; fees, up to 25 H. P., \$5; to 40 H. P., \$8; to 50 H. P., \$15; above 50 H. P., \$20; electrics, \$5; chauffeur's license, \$5.

Speed.—Reasonable and proper. In cities in built-up districts, 10 mi. per hr.; in residential districts, 15 mi. per hr.;

elsewhere in cities, 20 mi. per hr.; on curves, etc., 6 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Exempt for 60 da. with home tags if reciprocal exemption is granted.

INDIANA

Registration.—Annually, with Secretary of State; fee, to 25 H. P., \$5; to 40 H. P., \$8; to 50 H. P., \$15; above 50 H. P., \$20; electrics, \$3; chauffeur's license, \$2.

Speed.—Reasonable and proper. In built-up districts, 10 mi. per hr.; in residential districts, 15 mi. per hr.; elsewhere in cities, 20 mi. per hr.; on curves, etc., 6 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Exempt for 60 da. with home tags.

IOWA

Registration.—Annually, with Secretary of State; fee, up to 20 H. P., \$8; 40 c. for each H. P. over 20. No chauffeur's license required.

Speed.—Reasonable and proper, not exceeding 25 mi. per hr.

Non-Residents.—Exempt with home tags and reciprocal exemption.

KANSAS

Registration.—Annually, with County Treasurer; fee, \$5. For 6 mo. or less, \$2.50. No chauffeur's license.

Speed.—Reasonable and proper; on curves, etc., 8 mi. per hr.; at street intersections, 6 mi. per hr.; in municipalities, 12 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Reciprocal exemption with home tags.

KENTUCKY

Registration.—Annually, with Commissioner of Motor Vehicles; fee, up to 25 H. P., \$6; up to 50 H. P., \$11; above 51 H. P., \$20; chauffeur's license, \$2.

Speed.—Reasonable and proper; in built-up sections, 10 mi. per hr.; in residential sections, 15 mi. per hr.; on curves, etc., 8 mi. per hr.; elsewhere, 20 mi. per hr.

Non-Residents.—Reciprocal exemption with home tags.

LOUISIANA

Registration.—Annually, with Secretary of State; fee, 25 c. per H. P., with minimum of \$5; half fee after August 1. No state license for chauffeurs, but subject to local regulation.

Speed.—Reasonable and prudent.

Non-Residents.—Reciprocal exemption with home tags.

MAINE

Registration.—Annually, with Secretary of State; fee, up to 20 H. P., \$5; up to 35 H. P., \$10; over 35 H. P., \$15. Owner's and chauffeur's driving license, \$2.

Speed.—In built-up sections, 10 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Exempt for 30 da. with home tags.

MARYLAND

Registration.—Annually, with Commissioner of Motor Vehicles; fee, up to 10 H. P. \$5; up to 20 H. P., \$10; up to 30 H. P., \$15; up to 40 H. P., \$20; above 40 H. P., \$25. If registered after June 1, a reduction of one-twelfth for each month is made in the fees. Owner's driving license is perpetual, fee, \$2; chauffeur's license is annual, fee, \$5.

Speed.—Reasonable and proper. In built-up sections, 8 mi. per hr.; in thinly settled sections, 12 mi. per hr.; elsewhere, 25 mi. per hr. Speed must be reduced on curves, etc.

Non-Residents.—Exempt for 14 da. with home tags.

MASSACHUSETTS

Registration.—Annually, with State Highway Commission; fee, up to 19 H. P., \$5; up to 29 H. P., \$10; up to 39 H. P., \$15; up to 49 H. P., \$20; above 50 H. P., \$25; owner's and chauffeur's driving license, \$2, with annual renewal fee of 50 c.

Speed.—Reasonable and proper; in built-up sections, 15 mi. per hr.; on curves, etc., 8 mi. per hr.; elsewhere, 20 mi. per hr.

Non-Residents.—Reciprocal exemption for 30 da.

MICHIGAN

Registration.—Annually, with Secretary of State; fee, \$3; chauffeur's license, \$2.

Speed.—Reasonable and proper; in built-up sections, 10 mi. per hr.; elsewhere in municipalities, 15 mi. per hr.; in open country, 25 mi. per hr.; speed on curves, etc. must be reduced.

Non-Residents.—Reciprocal exemption.

MINNESOTA

Registration.—Every 3 yr., with Secretary of State; fee, \$1.50; chauffeur's license, \$1.50, with renewal fee of \$1.

Speed.—Reasonable and proper, not to exceed 25 mi. per hr.; on curves, etc., $7\frac{1}{2}$ mi. per hr.

Non-Residents.—Exempt for 30 da. with home tags.

MISSISSIPPI

Registration.—Annually, with Tax Collector of County; fee, 36 c. per H. P., reduced one-half after third payment; electricians, \$4.80. No chauffeur's license required. Price of tags, \$2, for life of car.

Speed.—Reasonable and prudent, but municipalities may enact their own regulations.

Non-Residents.—Exempt for 60 da. with home tags.

MISSOURI

Registration.—Annually, with Secretary of State; fee, up to 11 H. P., \$2; up to 23 H. P., \$3; up to 35 H. P., \$5; up to 47 H. P., \$7; up to 59 H. P., \$8; up to 71 H. P., \$10; 72 H. P. and over, \$12; chauffeur's license, \$1.50.

Speed.—Careful and prudent, not to exceed 25 mi. per hr. for $\frac{1}{2}$ mi.

Non-Residents.—Exempt for 20 da. with home tags.

MONTANA

Registration.—Annually, with Secretary of State; fee, \$2 chauffeur's license, \$2.

Speed.—Reasonable and proper.

Non-Residents.—Reciprocal exemption with home tags.

NEBRASKA

Registration.—Annually, with Secretary of State; fee, \$3, reduced to \$1.50 after July 1. No chauffeur's license required.

Speed.—Reasonable and proper; in municipalities, 12 mi. per hr.; at crossings, 6 mi. per hr.; on curves, etc., 8 mi. per hr. Must come to a full stop back of street cars receiving or discharging passengers.

Non-Residents.—Exempt for 30 da. with home tags.

NEVADA

Registration.—Annually, with Secretary of State; fee, 12½ c. per H. P., with minimum of 20 H. P. No chauffeur's license required.

Speed.—Reasonable and proper, with local speed regulations.

Non-Residents.—Exempt for 30 da. with home tags.

NEW HAMPSHIRE

Registration.—Annually, with Commissioner of Motor Vehicles; fee, up to 15 H. P., \$10; up to 30 H. P., \$15; up to 40 H. P., \$20; up to 50 H. P., \$25; up to 60 H. P., \$30; over 60 H. P., \$40; chauffeur's license, \$5; operator's license, \$3, with renewal fee for both of \$1.

Speed.—In built-up sections, 15 mi. per hr.; reduce speed on curves, etc.; elsewhere 25 mi. per hr.

Non-Residents.—Special registration at half rate for months of July, August, and September, otherwise same as residents. Operators and chauffeurs, if holding home state license, \$1; otherwise \$2 and must stand examination.

NEW JERSEY

Registration.—Annually, with Commissioner of Motor Vehicles; fee, to 10 H. P., \$4.50; to 29 H. P., \$7.50; 30 H. P. and over, \$15. Owner's and chauffeur's driving license, up to 30 H. P., \$2; above 30 H. P., \$4.

Speed.—In built-up sections, 12 mi. per hr.; on curves, etc., 8 mi. per hr.; at country crossings or within 200 ft. of horses on highways, 15 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Reciprocal exemption for car and chauffeur for 15 da.

NEW MEXICO

Registration.—Annually, with Secretary of State; fee, up to 11 H. P., \$2; up to 19 H. P., \$4; up to 29 H. P., \$6; up to

39 H. P., \$8; up to 49 H. P., \$10; 50 H. P. and over, \$12. No chauffeur's license required.

Speed.—Reasonable and proper.

Non-Residents.—Exempt for 60 da. with home tags.

NEW YORK

Registration.—Annually, with Secretary of State; fee, up to 25 H. P., \$5; up to 34 H. P., \$10; up to 49 H. P., \$15; 50 H. P. and over, \$25; chauffeur's license, \$5, with renewal fee of \$2.

Speed.—Careful and prudent, not exceeding 30 mi. per hr.

Non-Residents.—Reciprocal exemption.

NORTH CAROLINA

Registration.—Annually, with Secretary of State; fee, up to 25 H. P., \$5; up to 40 H. P., \$7.50; over 40 H. P., \$10. Between March 1 and June 30, registration fee is one-half the regular fee. No chauffeur's license.

Speed.—Reasonable and proper; in built-up sections, 10 mi. per hr.; elsewhere in municipalities, 15 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Exempt for 15 da.

NORTH DAKOTA

Registration.—Annually, with Secretary of State; fee, \$3. No chauffeur's license required.

Speed.—Reasonable and proper; in city limits, 10 mi. per hr.; on curves, etc., $7\frac{1}{2}$ mi. per hr.; elsewhere, 30 mi. per hr.

Non-Residents.—Exempt with home tags.

OHIO

Registration.—Annually, with Secretary of State; fee, \$5: electrics, \$3; chauffeur's license, \$3.

Speed.—In built-up sections, 8 mi. per hr., and 15 mi. per hr. in other parts of municipalities; elsewhere, 20 mi. per hr.

Non-Residents.—Exempt with home tags.

OKLAHOMA

Registration.—Annually, with Department of Highways; fee, 50 c. per H. P. for first year; 40 c. per H. P. for second year,

30 c. per H. P. for third year, and 20 c. per H. P. each year thereafter. No chauffeur's license required.

Speed.—Reasonable and proper.

Non-Residents.—Not exempt.

OREGON

Registration.—Annually, with Secretary of State; fee, up to 26 H. P., \$3; up to 36 H. P., \$5; up to 40 H. P., \$7.50; over 40 H. P., \$10; electrics, \$3; chauffeur's license, \$2, and after August 1, \$1.

Speed.—Reasonable and proper, not over 25 mi. per hr.

Non-Residents.—Exempt for 30 da. with home tags.

PENNSYLVANIA

Registration.—Annually, with State Highway Commissioner; fee, up to 19 H. P., \$5; up to 34 H. P., \$10; up to 49 H. P., \$15; 50 H. P. and over, \$20; after July 1, fees are reduced one-half; chauffeur's license, \$2.

Speed.—Reasonable and proper; 24 mi. per hr. unless roads are sign-posted otherwise.

Non-Residents.—Reciprocal exemption.

RHODE ISLAND

Registration.—Annually, with State Board of Public Roads; fee, up to 20 H. P., \$5; up to 30 H. P., \$10; up to 40 H. P., \$15; over 40 H. P., \$25; chauffeur's license, \$1.

Speed.—In built-up sections, 15 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Exempt for 10 da.

SOUTH CAROLINA

Registration.—With Clerk of County Court; fee, \$1; no chauffeur's license required.

Speed.—Reasonable and proper; 6 mi. per hr. on curves, etc., and 15 mi. per hr. elsewhere.

Non-Residents.—No provision made.

SOUTH DAKOTA

Registration.—Annually, with County Treasurer; fee, \$3. No chauffeur's license required.

Speed.—Reasonable and proper.

Non-Residents.—Reciprocal exemption with home tags.

TENNESSEE

Registration.—Annually, with County Clerk; fee, more than four passengers capacity, \$7.50; four passengers or less capacity, \$5; after September fee is reduced one-half; no chauffeur's license required.

Speed.—Reasonable and proper.

Non-Residents.—Exempt with home tags.

TEXAS

Registration.—With County Clerk; fee, 50 c. per H. P.; no chauffeur's license required.

Speed.—Reasonable and proper; in built-up sections of municipalities, 8 mi. per hr.; elsewhere, 18 mi. per hr.

Non-Residents.—No provision.

UTAH

Registration.—Annually, with Secretary of State; fee, up to 25 H. P., \$5; up to 40 H. P., \$10; over 40 H. P., \$15; electrics, \$10. After June 30 fee is reduced one-half. Chauffeur's license, \$2.

Speed.—Reasonable and proper.

Non-Residents.—Exempt 30 da. with home tags.

VERMONT

Registration.—Annually, with Secretary of State; fee, first year, \$1 per H. P.; second year, 75 c. per H. P.; third year and after, 50 c. per H. P. After August 1 fees are reduced one-half. Owner's and chauffeur's driving license, \$2.

Speed.—In built-up sections, 10 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Reciprocal exemption; 3 mo. certificate for one-quarter the regular fees.

VIRGINIA

Registration.—Annually, with Secretary of State; fee, up to 20 H. P., \$5; up to 44 H. P., \$10; 45 H. P. and over, \$15; chauffeur's license, \$2.50.

Speed.—In municipalities and on curves, etc., 8 mi. per hr.; elsewhere, 20 mi. per hr.

Non-Residents.—Exempt for 14 da.

WASHINGTON

Registration.—Annually, with County Auditor; fee, up to 25 H. P., \$3; up to 39 H. P., \$5; 40 H. P. and over, \$7.50; no chauffeur's license required.

Speed.—Reasonable and proper. In built-up sections, 12 mi. per hr.; on curves, etc., 4 mi. per hr.; elsewhere, 30 mi. per hr.

Non-Residents.—Exempt for 90 da. with home tags.

WEST VIRGINIA

Registration.—Annually, with State Auditor; fee, \$10; chauffeur's license, \$2.

Speed.—In municipalities, 15 mi. per hr.; elsewhere, 20 mi. per hr.

Non-Residents.—Reciprocal exemption with home tags.

WISCONSIN

Registration.—Perpetual, with Secretary of State; fee, \$5; no chauffeur's license required.

Speed.—Reasonable and proper; on curves, etc., 8 mi. per hr.; in municipalities, 15 mi. per hr.; elsewhere, 25 mi. per hr.

Non-Residents.—Exempt with home tags.

WYOMING

Registration.—Annually, with Secretary of State; fee, \$5; no chauffeur's license required.

Speed.—Reasonable and proper; in municipalities, 12 mi. per hr.; on curves, etc., 8 mi. per hr.; at street crossings, 6 mi. per hr.

Non-Residents.—Exempt with home tags.

DATA RELATING TO TIRES AND RIMS

MAXIMUM CARRYING CAPACITIES OF SOLID TIRES

Single		Twin	
Size	Extreme Load per Wheel	Size	Extreme Load per Wheel
Inches	Pounds	Inches	Pounds
2	500	2½	1,900
2½	750	3	2,500
3	950	3½	3,500
3½	1,375	4	5,000
4	1,750	5	6,000
5	2,000	6	8,000
6	3,000		
7	4,000		

METRIC TIRE SIZES AND THEIR AMERICAN EQUIVALENTS

Metric Sizes	*Approximate Size	Metric Sizes	*Approximate Size
Millimeters	Inches	Millimeters	Inches
650×65	26×2½	870×90	34×3½
700×65	28×2½	910×90	36×3½
750×65	30×2½	960×90	38×3½
800×65	32×2½	1,010×90	40×3½
830×65	33×2½	815×105	32×4
860×65	34×2½	875×105	34×4
700×85	28×3¼	915×105	36×4
750×85	30×3¼	820×120	32×4½-5
800×85	32×3½	850×120	33×4½-5
860×85	34×3½	880×120	34×4½-5
760×90	30×3½	920×120	36×4½-5
810×90	32×3½	1,020×120	40×4½-5
840×90	32×3½	1,080×120	42×4½-5

*Actual sizes of metric tires are not exactly the same as any American tires.

CLINCHER RIM MEASUREMENTS

Size Inches	Inside Diameter of Rims for Wood Wheels Inches	Diameter of Rim at Tire Seat for Wood and Wire Wheels Inches	Size Inches	Inside Diameter of Rims for Wood Wheels Inches	Diameter of Rim at Tire Seat for Wood and Wire Wheels Inches
26×22	20.834	21	34×3	27	28
28×22	21.834	22	36×3	29	30
30×22	23.834	24	28×3½	20½	21
32×22	26.834	27	30×3½	22½	23
34×22	28.834	29	32×3½	24½	25
36×22	30.834	31	34×3½	26½	27
26×23	19.834	20	36×3½	28½	29
28×23	21.834	22	30×4	21½	22
30×23	23.834	24	32×4	23½	24
32×23	25.834	26	34×4	25½	26
34×23	27.834	28	36×4	27½	28
36×23	29.834	30	28×4½	18½	19
26×24	20	21	30×4½	20½	21
28×24	21	22	32×4½	22½	23
30×24	23	24	34×4½	24½	25
32×24	26	27	36×4½	26½	27
34×24	28	29	28×5	17½	18
36×24	30	31	30×5	19½	20
26×25	19	20	32×5	21½	22
28×25	21	22	34×5	23½	24
30×25	23	24	36×5	25½	26
32×25	25	26	40×5	29½	30

Note that the 28×2½ and 30×2½ tires are made interchangeable with the 28×3 and 30×3 tires.

STANDARD, UNIVERSAL, TYPES 1 AND 2, QUICK-DETACHABLE RIM MEASUREMENTS

(United Rim Company, Akron, Ohio)

Size of Tire	Diameter of Rim at Tire Seat	Inside Diameter of Rims	Size of Tire	Diameter of Rim at Tire Seat	Inside Diameter of Rims
Inches	Inches	Inches	Inches	Inches	Inches
26×2 $\frac{1}{2}$	21	20 $\frac{3}{4}$	40×4	32	31 $\frac{1}{2}$
28×2 $\frac{1}{2}$	22	21 $\frac{3}{4}$	42×4	34	33 $\frac{1}{2}$
30×2 $\frac{1}{2}$	24	23 $\frac{3}{4}$	44×4	36	35 $\frac{1}{2}$
32×2 $\frac{1}{2}$	27	26 $\frac{3}{4}$	46×4	38	37 $\frac{1}{2}$
34×2 $\frac{1}{2}$	29	28 $\frac{3}{4}$	48×4	40	39 $\frac{1}{2}$
36×2 $\frac{1}{2}$	31	30 $\frac{3}{4}$			
26×3	20	19 $\frac{3}{4}$	32×4 $\frac{1}{2}$	23	22 $\frac{1}{2}$
28×3	22	21 $\frac{3}{4}$	34×4 $\frac{1}{2}$	25	24 $\frac{1}{2}$
30×3	24	23 $\frac{3}{4}$	36×4 $\frac{1}{2}$	27	26 $\frac{1}{2}$
32×3	26	25 $\frac{3}{4}$	38×4 $\frac{1}{2}$	29	28 $\frac{1}{2}$
34×3	28	27 $\frac{3}{4}$	40×4 $\frac{1}{2}$	31	30 $\frac{1}{2}$
36×3	30	29 $\frac{3}{4}$	42×4 $\frac{1}{2}$	33	32 $\frac{1}{2}$
			44×4 $\frac{1}{2}$	35	34 $\frac{1}{2}$
28×3 $\frac{1}{2}$	21	20 $\frac{1}{2}$	46×4 $\frac{1}{2}$	37	36 $\frac{1}{2}$
30×3 $\frac{1}{2}$	23	22 $\frac{1}{2}$	48×4 $\frac{1}{2}$	39	38 $\frac{1}{2}$
32×3 $\frac{1}{2}$	25	24 $\frac{1}{2}$			
34×3 $\frac{1}{2}$	27	26 $\frac{1}{2}$	36×5 $\frac{1}{2}$	25	24 $\frac{1}{2}$
36×3 $\frac{1}{2}$	29	28 $\frac{1}{2}$	38×5 $\frac{1}{2}$	27	26 $\frac{1}{2}$
			40×5 $\frac{1}{2}$	29	28 $\frac{1}{2}$
30×4	22	21 $\frac{1}{2}$	42×5 $\frac{1}{2}$	31	30 $\frac{1}{2}$
32×4	24	23 $\frac{1}{2}$	44×5 $\frac{1}{2}$	33	32 $\frac{1}{2}$
34×4	26	25 $\frac{1}{2}$	46×5 $\frac{1}{2}$	35	34 $\frac{1}{2}$
36×4	28	27 $\frac{1}{2}$	48×5 $\frac{1}{2}$	37	36 $\frac{1}{2}$
38×4	30	29 $\frac{1}{2}$			

STANDARD, UNIVERSAL, TYPES 1 AND 2, QUICK- DETACHABLE, DEMOUNTABLE RIM MEASUREMENTS

(United Rim Company, Akron, Ohio)

Size of Tire	Inside Diameter of Felloe Band	Size of Tire	Inside Diameter of Felloe Band	Size of Tire	Inside Diameter of Felloe Band
Inches	Inches	Inches	Inches	Inches	Inches
28×2½	20½	36×2½	27½	36×4½	25½
30×2½	22½	30×4	20½	38×4½	27½
32×2½	25½	32×4	22½	40×5	28½
34×2½	27½	34×4	24½	40×4½	29½
36×2½	29½	36×4	26½	42×4½	31½
26×3	18½	38×4	28½	44×4½	33½
28×3	20½	40×4	30½	46×4½	35½
30×3	22½	42×4	32½	48×4½	37½
32×3	24½	44×4	34½	36×5½	23½
34×3	26½	46×4	36½	38×5½	25½
36×3	28½	48×4	38½	40×5½	27½
28×3½	19½	32×4½	21½	42×5½	29½
30×3½	21½	34×5	22½	44×5½	31½
32×3½	23½	34×4½	23½	46×5½	33½
34×3½	25½	36×5	24½	48×5½	35½

STANDARD, UNIVERSAL, TYPE 3, QUICK- DETACHABLE, DEMOUNTABLE-RIM MEASUREMENTS

(United Rim Company, Akron, Ohio)

Size of Tire	Inside Diameter of Felloe Band	Size of Tire	Inside Diameter of Felloe Band	Size of Tire	Inside Diameter of Felloe Band
Inches	Inches	Inches	Inches	Inches	Inches
30×3½	22	40×4	31	42×4½	31½
32×3½	24	42×4	33	34×5	22½
34×3½	26	30×4½	19½	36×5	24½
36×3½	28	32×4½	21½	40×5	28½
30×4	21	34×4½	23½	36×5½	23½
32×4	23	36×4½	25½	38×5½	25½
34×4	25	38×4½	27½		
36×4	27	40×4½	29½		

WHEEL DIMENSIONS FOR SOLID SINGLE AND DUAL TIRES (*Society of Automotive Engineers*)

Dimension	Normal Outside Diameter of Tire, Inches						
	30	32	34	36	38	40	42
Wheel diameter over steel band, inches.....	24	26	28	30	32	34	36
Exact wheel circumference over steel band, no shrinkage allowed, inches.....	75 $\frac{3}{4}$	81 $\frac{1}{2}$	87 $\frac{1}{4}$	94 $\frac{1}{2}$	100 $\frac{1}{2}$	106 $\frac{1}{4}$	113 $\frac{1}{4}$
Tolerance over exact circumference of bands before application to wheel, inches.....	75 $\frac{3}{4}$	81 $\frac{1}{2}$	88 $\frac{1}{4}$	94 $\frac{1}{2}$	100 $\frac{1}{2}$	106 $\frac{1}{2}$	113 $\frac{1}{2}$
Tolerance over exact circumference of bands after application to wheel, inches.....	75 $\frac{3}{4}$	81 $\frac{1}{2}$	88 $\frac{3}{4}$	94 $\frac{3}{4}$	100 $\frac{3}{4}$	106 $\frac{1}{4}$	113 $\frac{1}{4}$

WHEEL DIMENSIONS FOR SOLID TIRES

(Society of Automotive Engineers)

Sectional Size of Tire Inches	Single Tires			Dual Tires		
	Width of Felloe and Band Inches	Thick- ness of Steel Band Inch	Mini- mum Thick- ness of Felloe Inches	Width of Felloe and Band Inches	Thick- ness of Steel Band Inch	Mini- mum Thick- ness of Felloe Inches
2	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	4	1 $\frac{1}{4}$	1 $\frac{1}{4}$
2 $\frac{1}{2}$	1 $\frac{3}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	5	1 $\frac{1}{4}$	1 $\frac{1}{4}$
3	2 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	6	1 $\frac{1}{4}$	1 $\frac{1}{4}$
3 $\frac{1}{2}$	2 $\frac{3}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	7	1 $\frac{1}{4}$	1 $\frac{1}{4}$
4	3 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	8	1 $\frac{1}{4}$	1 $\frac{1}{4}$
4 $\frac{1}{2}$	3 $\frac{3}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	9	1 $\frac{1}{4}$	1 $\frac{1}{4}$
5	4 $\frac{1}{4}$	1 $\frac{1}{4}$	2	10	1 $\frac{1}{4}$	2
5 $\frac{1}{2}$	4 $\frac{3}{4}$	1 $\frac{1}{4}$	2	11	1 $\frac{1}{4}$	2
6	5 $\frac{1}{4}$	1 $\frac{1}{4}$	2	12	1 $\frac{1}{4}$	2
6 $\frac{1}{2}$	5 $\frac{3}{4}$	1 $\frac{1}{4}$	2 $\frac{1}{4}$	13	1 $\frac{1}{4}$	2 $\frac{1}{4}$
7	6 $\frac{1}{4}$	1 $\frac{1}{4}$	2 $\frac{1}{4}$	14	1 $\frac{1}{4}$	2 $\frac{1}{4}$
7 $\frac{1}{2}$	6 $\frac{3}{4}$	1 $\frac{1}{4}$	2 $\frac{1}{4}$	15	1 $\frac{1}{4}$	2 $\frac{1}{4}$
8	7 $\frac{1}{4}$	1 $\frac{1}{4}$	2 $\frac{1}{4}$	16	1 $\frac{1}{4}$	2 $\frac{1}{4}$

HORSEPOWER CALCULATIONS

INDICATED HORSEPOWER

The *indicated horsepower*, so called because it is measured by means of an indicator and sometimes abbreviated to I. H. P., is the power applied to the piston of the engine by the explosion and expansion of the gases. The indicated horsepower of an automobile engine may be calculated by the formula:

$$I. H. P. = \frac{p l a n}{33,000}$$

in which p = mean effective pressure, in pounds per square inch;
 l = length of piston stroke, in feet;
 a = area of piston, in square inches;
 n = number of explosions per minute.

In determining the value of n , all of the cylinders must be taken into account; for instance, in the case of a four-cylinder, four-cycle engine running at a speed of 500 r. p. m., $n=1,000$. The mean effective pressure of a gasoline automobile engine can be determined by an ordinary steam-engine indicator when the speed of the engine does not exceed 500 r. p. m. At higher speeds, a manograph must be used. This instrument records by means of a streak of light the outline of the indicator card, which can then be photographed and permanently retained.

To calculate approximately the maximum horsepower that an engine is or should be capable of developing, without taking indicator diagrams, the mean effective pressure may be assumed for the formula just given. For the ordinary, four-cycle, gasoline automobile engine, this pressure can be assumed at between 75 and 100 lb., depending on the compression pressure. For two-cycle engines, in which the compression is usually lower than in the four-cycle, mean effective pressure of not over 70 or 75 lb. should be used.

The indicated horsepower of a gasoline engine is at best only an approximation and is probably used to the best advantage in designing, when the horsepower is desired before the engine is built. It is also employed in finding the mechanical efficiency of an automobile engine. The mechanical efficiency is found by dividing the actual horsepower derived from an engine by the indicated horsepower.

BRAKE HORSEPOWER

The *brake horsepower* (abbreviated to B. H. P.), is the name given to the power delivered by the engine to the machinery it is driving. It is so called because it is measured by a brake. The data necessary for computing the brake horsepower of a gasoline engine is usually found by means of an ordinary Prony brake or dynamometer. The *Prony brake* consists of two or more brake blocks or friction blocks attached to an arm or lever, one end of which rests on a pair of scales. The brake blocks are fitted with bolts, or with a strap and bolts, so that they may be tightened on the flywheel of the engine by adjusting the nuts on the ends of the bolts. The Prony brake is used

by placing it in position on the flywheel with the arm resting on the scales, then starting the engine and tightening the blocks until a certain number of revolutions per minute is obtained. A record is made of the pressure exerted at the end of the brake arm, the length of the arm, and the number of revolutions made by the crank-shaft in one minute.

The brake horsepower is calculated by the formula:

$$B. H. P. = \frac{2 \pi p l n}{33,000}$$

in which $\pi = 3.1416$;

p = pressure exerted at end of brake arm, in pounds;

l = length of brake arm, in feet;

n = number of revolutions per minute.

Many automobile manufacturers test their engines by coupling them to a dynamo, measuring the output by taking the readings of the voltmeter and ammeter. The general rule for finding the horsepower from these readings is to multiply together the voltmeter and ammeter readings and to divide the product by 746. If the quotient is divided again by the efficiency of the dynamo, the true horsepower delivered by the engine to the dynamo is obtained.

S. A. E. HORSEPOWER FORMULA

The formula that has been adopted by the Society of Automotive Engineers for calculating the rated horsepower of a four-cycle gasoline automobile engine is:

$$H. P. = \frac{D^2 N}{2.5}$$

in which D = cylinder diameter, in inches;

N = number of cylinders.

This formula is based on a piston speed of 1,000 ft. per min., an average M. E. F. of 90 lb. per sq. in., and a mechanical efficiency of 75%, and is used principally for comparing one car with another and for obtaining power ratings. This formula is not used by all automobile manufacturers, however.

For two-cycle engines, the horsepower may be taken as approximately 1.65 of that of a four-cycle engine calculated by the formula just given.

HORSEPOWER BY S. A. E. FORMULA, FOUR-CYCLE ENGINES

(Calculated by Automobile School, International Correspondence Schools)

Cylinder Bore		Rated Horsepower					
Inches	Milli- meters	1 Cylin- der	2 Cylin- ders	4 Cylin- ders	6 Cylin- ders	8 Cylin- ders	12 Cylin- ders
2 1/8	63.5	2.50	5.00	10.00	15.00	20.00	30.00
2 1/4	66.7	2.76	5.51	11.02	16.54	22.05	33.08
2 3/8	69.9	3.03	6.05	12.10	18.15	24.20	36.30
2 1/2	73.0	3.31	6.61	13.23	19.84	26.45	39.68
3	76.2	3.60	7.20	14.40	21.60	28.80	43.20
3 1/8	79.4	3.91	7.81	15.63	23.44	31.25	46.88
3 1/4	82.6	4.23	8.45	16.90	25.35	33.80	50.70
3 3/8	85.7	4.56	9.11	18.23	27.34	36.45	54.68
3 1/2	88.9	4.90	9.80	19.60	29.40	39.20	58.80
3 3/4	92.1	5.26	10.51	21.03	31.54	42.05	63.08
3 7/8	95.3	5.63	11.25	22.50	33.75	45.00	67.50
4	98.4	6.01	12.01	24.03	36.04	48.05	72.08
4 1/8	101.6	6.40	12.80	25.60	38.40	51.20	76.80
4 1/4	104.8	6.81	13.61	27.23	40.84	54.45	81.68
4 3/8	108.0	7.23	14.45	28.90	43.35	57.80	86.70
4 1/2	111.1	7.66	15.31	30.63	45.94	61.25	91.88
4 3/4	114.3	8.10	16.20	32.40	48.60	64.80	97.20
4 7/8	117.5	8.56	17.11	34.23	51.34	68.45	102.68
5	120.7	9.03	18.05	36.10	54.15	72.20	108.30
5 1/8	123.8	9.51	19.01	38.03	57.04	76.05	114.08
5 1/4	127.0	10.00	20.00	40.00	60.00	80.00	120.00
5 3/8	130.2	10.51	21.01	42.03	63.04	84.05	126.08
5 1/2	133.4	11.03	22.05	44.10	66.15	88.20	132.30
5 3/4	136.5	11.56	23.11	46.23	69.34	92.45	138.68
5 7/8	139.7	12.10	24.20	48.40	72.60	96.80	145.20
6	142.9	12.66	25.31	50.63	75.94	101.25	151.88
6 1/8	146.1	13.23	26.45	52.90	79.35	105.80	158.70
6 1/4	149.2	13.81	27.61	55.23	82.84	110.45	165.68
6 3/8	152.4	14.40	28.80	57.60	86.40	115.20	172.80

MISCELLANEOUS USEFUL DATA

SOLDERING ALUMINUM

(Chilton Automobile Directory)

There are various compounds on the market for soldering aluminum, but this operation depends more on the workman than on the solder, and unless considerable experience has been had it is probably better to purchase solder than to attempt making it. Zinc can be used but does not form a very strong joint. Tin can be used, is more nearly the color of aluminum, is stronger than zinc, but is very difficult to work. A small proportion of phosphor tin added to pure tin makes it work more readily and is the basis of most aluminum solder.

The chief difficulty in soldering aluminum is that the heat is dissipated so rapidly that it cools the soldering iron and, furthermore, aluminum oxidizes instantly upon exposure to the air. This extremely thin film effectively prevents a perfect union being made. If the parts are well heated and melted solder kept hot while the iron is allowed to stand on it, the surface can be scraped beneath the melted solder by the point of the soldering iron, thus preventing to a certain extent the oxidization. In this way the metal can be tinned. When both parts to be brought together are well tinned, the parts can be united with some chance of success, nitrate of silver, resin, or zinc chloride being used as a flux. A soldering tool of nickel gives more satisfactory results than a copper one, as the latter alloys with the tin and soon becomes rough.

If the surface is of such a shape that it cannot be readily cleaned by scraping, it can be cleaned by dipping it into a solution of nitric acid in three times its bulk of hot water containing about 5% of commercial hydrofluoric acid. This causes a slight action on the surface of the metal as shown by bubbles. Rinse the metal after removing from the acid bath and dry in hot sawdust.

The following formula, in the hands of a competent man, can be used to unite aluminum or aluminoid parts: Tin, 10 parts; cadmium, 10 parts; zinc, 10 parts; lead, 1 part. The

parts to be united must be thoroughly cleansed and allowed to stand 2 or 3 hr. in a strong solution of hyposulphate of soda before being operated upon, or cleaned in the acid bath described.

METAL POLISHES

Brass Polishes.—Rub with mixture of salt and vinegar, or use oxalic acid; when clean, wash well with water and polish with any good brass polish. A good paste is made of 1 part of oxalic acid mixed with 6 parts (by weight) of rottenstone and moistened with a liquid consisting of equal parts of whale oil and turpentine.

Another polish consists of 25 parts of jewelers' red, 15 parts of oil of turpentine, 25 parts of oil of stearine, 45 parts of animal charcoal, and sufficient alcohol to make the mass liquid. Apply with a stiff brush, and after the polish has dried, rub with a dry cloth.

Aluminum Polish.—Use equal parts of rum and olive oil.

UNITED STATES STANDARD 60° SCREW THREADS

Diameter of Screw Inches	Threads per Inch	Diameter at Root of Thread Inches	Width of Flat at Top and Bottom of Thread Inch
$\frac{1}{16}$	20	.1850	.0062
$\frac{1}{8}$	18	.2403	.0069
$\frac{3}{16}$	16	.2936	.0078
$\frac{1}{4}$	14	.3447	.0089
$\frac{5}{16}$	13	.4001	.0096
$\frac{3}{8}$	12	.4542	.0104
$\frac{7}{16}$	11	.5069	.0114
$\frac{1}{2}$	10	.6201	.0125
$\frac{5}{8}$	9	.7307	.0139
1	8	.8376	.0156
$1\frac{1}{16}$	7	.9394	.0179
$1\frac{1}{8}$	7	1.0644	.0179
$1\frac{1}{4}$	6	1.1585	.0208
$1\frac{3}{8}$	6	1.2835	.0208
$1\frac{1}{2}$	$5\frac{1}{2}$	1.3888	.0227
$1\frac{3}{4}$	5	1.4902	.0250
$1\frac{7}{8}$	5	1.6152	.0250
2	$4\frac{1}{2}$	1.7113	.0278

SOCIETY OF AUTOMOTIVE ENGINEERS' SCREW STANDARD

Diameter of Screw Inches	Threads per Inch	Height of Castellated Nut Inches	Height of Plain Nut Inches	Diameter of Nuts and Bolt-heads Across Flats, Inches	Height of Bolt Head Inches	Tap Drills Inches
$\frac{1}{16}$	28	$\frac{1}{16}$	$\frac{7}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
$\frac{1}{8}$	24	$\frac{1}{8}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{3}{16}$	24	$\frac{3}{16}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{1}{2}$	20	$\frac{1}{2}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{5}{8}$	20	$\frac{5}{8}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{3}{4}$	18	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{7}{8}$	18	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
1	16	1	$\frac{13}{16}$	1	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{1}{8}$	16	$1\frac{1}{8}$	$\frac{13}{16}$	1	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{1}{4}$	16	$1\frac{1}{4}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{3}{4}$	14	$1\frac{3}{4}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
2	14	2	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$2\frac{1}{2}$	12	$2\frac{1}{2}$	$\frac{13}{16}$	2	$\frac{1}{8}$	$\frac{1}{8}$
3	12	3	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$3\frac{1}{2}$	12	$3\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
4	12	4	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$4\frac{1}{2}$	12	$4\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
5	12	5	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$5\frac{1}{2}$	12	$5\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
6	12	6	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$6\frac{1}{2}$	12	$6\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
7	12	7	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$7\frac{1}{2}$	12	$7\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
8	12	8	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$8\frac{1}{2}$	12	$8\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
9	12	9	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$9\frac{1}{2}$	12	$9\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
10	12	10	$\frac{13}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$

Thread is U. S. Standard; length of threaded part, $1.5 \times$ diameter; screws, screw heads, and plain nuts are left soft; castellated nuts are case-hardened. For soft materials, as cast iron, brass, bronze, or aluminum, use U. S. Standard pitches of thread. The body diameters of the screws shall be .001 in. less than the nominal diameter, with a plus tolerance of zero and a minus tolerance of .002 in. Nuts shall be a good fit. The taps shall be from .002 to .003 in. large.

ENGLISH AND METRIC SPEED EQUIVALENTS

Velocity, in feet per second = miles per hour $\times 1.467$. 1 mi. per hr. = 1.467 ft. per sec. = 88 ft. per min. = .44 meter per sec. = 26.4 meters per min.

1 kilometer per hr. = .278 meter per sec. = 54.7 ft. per min. = .621 mi. per hr.

WIRE GAUGES

No. of Wire Gauge	American or Brown & Sharpe Inch	Birmingham or Stubs' Iron Wire Inch	Washburn & Moen Inch	Polished Drill or Stubs' Iron Wire Inch
0000	.46	.454	.3938	
000	.40964	.425	.3625	
00	.3648	.38	.3310	
0	.32486	.34	.3065	
1	.2893	.3	.2830	.227
2	.25763	.284	.2625	.219
3	.22942	.259	.2437	.212
4	.20431	.238	.2253	.207
5	.18194	.22	.2070	.204
6	.16202	.203	.1920	.201
7	.14428	.18	.1770	.199
8	.12849	.165	.1620	.197
9	.11443	.148	.1483	.194
10	.10189	.134	.1350	.191
11	.090742	.12	.1205	.188
12	.080808	.109	.1055	.185
13	.071961	.095	.0915	.182
14	.064084	.083	.0800	.180
15	.057068	.072	.0720	.178
16	.05082	.065	.0625	.175
17	.045257	.058	.0540	.172
18	.040303	.049	.0475	.168
19	.03589	.042	.0410	.164
20	.031961	.035	.0348	.161
21	.028462	.032	.03175	.157
22	.025347	.028	.0286	.155
23	.022571	.025	.0258	.153
24	.0201	.022	.0230	.151
25	.0179	.02	.0204	.148
26	.01594	.018	.0181	.146
27	.014195	.016	.0173	.143
28	.012641	.014	.0162	.139
29	.011257	.013	.0150	.134
30	.010025	.012	.0140	.127
31	.008928	.01	.0132	.120
32	.00795	.009	.0128	.115
33	.00708	.008	.0118	.112
34	.006304	.007	.0104	.110
35	.005614	.005	.0095	.108
36	.005	.054	.0090	.106
37	.004453			.103
38	.003965			.101
39	.003531			.099
40	.003144			.092

METRIC CONVERSION TABLES

U. S. TO METRIC

Linear

1 in. = 25.4001 mm.	1 yd. = .914402 m.
1 ft. = .304801 m.	1 mi. = 1.60935 km.

Square

1 sq. in. = 6.452 sq. cm.	1 sq. yd. = .836 sq. m.
1 sq. ft. = 9.29 sq. dm.	

Cubic

1 cu. in. = 16.387 cu. cm. or c. c.	1 cu. ft. = .02832 cu. m.
	1 cu. yd. = .765 cu. m.

Weight

1 gr. = 64.7989 mg.	1 troy oz. = 31.10348 g.
1 av. oz. = 28.3495 gr.	1 av. lb. = .45359 kg.

Capacity

1 fl. dr. = 3.7 cu. cm.	1 qt. = .94636 li.
1 fl. oz. = 29.57 ml.	1 gal. = 3.78544 li.

METRIC TO U. S.

Linear

1 m. = 39.37 in.	1 m. = 1.09361 yd.
1 m. = 3.28083 ft.	1 km. = .62137 mi.

Square

1 sq. cm. = .155 sq. in.	1 sq. m. = 1.196 sq. yd.
1 sq. m. = 10.7640 sq. ft.	

Cubic

1 cu. cm. = .061 cu. in.	1 cu. m. = 1.308 cu. yd.
1 cu. m. = 35.314 cu. ft.	

Weight

1 mg. = .01543 gr.	1 hg. = 3.5274 av. oz.
1 kg. = 15432.36 gr.	1 kg. = 2.20462 av. lb.

Capacity

1 ml. = .27 fl. dr.	1 l. = 1.0567 qt.
1 cl. = .338 fl. oz.	1 dl. = 2.6417 gal.

STRENGTH OF AUTOMOBILE STEELS

(Chilton Automobile Directory)

Grade	Elastic Limit Pounds per Sq. In.	Tensile Strength Pounds per Sq. In.	Elongation in 2 Inches Per Cent.	Reduction of Area Per Cent.	Condition
Chrome-nickel auto steel, No. 5-317..	65,650	91,200	27.0	64.3	Natural
Chrome-nickel auto steel, No. 5-317..	210,000	315,000	5.0	19.0	Tempered
Chrome-nickel auto steel, No. 5-317..	185,400	269,200	6.0	20.2	Tempered
Chrome-nickel auto steel, No. 5-317..	140,000	225,200	8.0	30.2	Tempered
Chrome-nickel auto steel, No. 5-317..	114,000	130,500	19.0	60.0	Toughened
Chrome-nickel auto steel, No. 3-317..	70,000	106,000	18.0	45.0	Natural
Chrome-nickel auto steel, No. 3-317..	135,000	197,000	9.0	37.0	Tempered
Chrome-nickel auto steel, No. 3-317..	90,000	110,000	25.0	55.0	Toughened
Dynamic auto steel, No. L3-14.....	103,800	121,390	20.0	60.0	Toughened
Special nickel steel, No. 575.....	80,000	99,000	21.0	58.2	Toughened
Special nickel steel, No. 575.....	87,000	102,000	21.0	62.0	Toughened
Crucible auto steel, No. L-521.....	160,000	175,000	7.0	30.0	Tempered
Special auto steel, No. 506.....	70,000	113,950	22.0	49.0	Natural
Special auto steel, No. 506.....	71,200	105,600	24.0	49.3	Natural
Weldable auto steel, No. 492.....	49,050	93,000	21.5	35.0	Natural
Weldable auto steel, No. 492.....	50,000	93,000	22.0	37.0	Natural
Auto steel, No. 478.....	48,300	74,500	29.0	43.0	Natural
Auto steel, No. 478.....	46,500	77,500	28.0	45.0	Natural

These tests were made with 2 in. test specimens of Carpenter Steel Co.'s auto steels in accordance with the standard specifications of the American Society for Testing Materials.

No. 5-317 is suitable for transmission gears, countershafts, and parts used for transmission of power.

No. 3-317 is a mild-temper steel suitable for case-hardened gears.

No. L 3-14 is an axle-steel able to withstand alternating stresses and dynamic strains.

No. 575 contains 3½% nickel and is manufactured to meet the U. S. Navy specification known as High Grade.

No. L-521 is a crucible gear-steel (moderate price); the gears can be tempered and do not require case hardening.

No. 506 is a manganese steel for shafts, bolts, etc., not subjected to excessive alternating or recurrent stresses.

GRADIENTS IN PER CENT. AND DEGREES

Grade		Equal to Angle of		Rise or Fall in 1 Mile Feet
Per Cent.	Units	Degrees	Minutes	
2.50	1 in 40	1	26	132
2.80	1 in 35	1	38	151
3.30	1 in 30	1	55	155
4.00	1 in 25	2	18	218
5.00	1 in 20	2	52	204
5.50	1 in 18	3	11	293
5.80	1 in 17	3	22	310
6.25	1 in 16	3	35	330
6.66	1 in 15	3	49	352
7.10	1 in 14	4	5	337
7.69	1 in 13	4	24	406
8.30	1 in 12	4	46	440
9.00	1 in 11	5	11	480
10.00	1 in 10	5	43	528
11.10	1 in 9	6	17	586
12.50	1 in 8	7	8	635
14.30	1 in 7	8	9	754
16.60	1 in 6	9	26	880
20.00	1 in 5	11	19	1,056

No. 492 is a special straight-carbon, crucible steel, with a fairly high tensile strength, suitable for axles and other parts that have to be welded.

No. 478 is a special, high-grade, open-hearth steel that is particularly adapted to such parts as are not subjected to unusual strains; it is suitable for axles, axle-journals, and various small parts of automobiles.

PICRIC ACID IN GASOLINE

A correspondent of *Motor Age* asked: "I would like information regarding the use of picric acid in motors to increase the power, and would like to know the quantity to use with safety." To this question the editor replied: "Picric acid, or ammonia nitrate, is an explosive compound which, when used in connection with gasoline as a fuel for motor cars, will increase the power of the combustion within the cylinder. To understand this, it is first necessary to consider the requisites for the combustion of a fuel in an internal-combustion engine. The gas used to produce this combustion is composed of the fuel contained in the gasoline vapor, which is rendered combustible by its admixture with the oxygen in the air, which composes the body of the gas. Picric acid possesses in its composition a considerable proportion of this element in addition to highly explosive fuel units, and when introduced into the charge of a gas engine, causes the power of the explosion to be augmented by the increase of the amount of oxygen. It furthermore possesses the peculiarity of being soluble in gasoline to only a limited degree, and for this reason is usually diluted with alcohol or ether before mixing with the gasoline.

"Best results are obtained by the use of 1 oz. of picric acid and 2 oz. of sal ammoniac to 5 oz. of gasoline. It is well to observe extreme caution in using anything of its kind, for gasoline motors are designed within comparatively narrow limits of strength, and can be expected to resist very little more than the pressure normally exerted by the combustion of pure gasoline gas.

"There is danger in handling this substance, and it is not recommended for use in motors."

TIME PER MILE EXPRESSED IN MILES PER HOUR

(Chilton Automobile Directory)

Time for 1 Mile		Miles per Hour	Time for 1 Mile		Miles per Hour	Time for 1 Mile		Miles per Hour
Min.	Sec.		Min.	Sec.		Min.	Sec.	
	36	100.00	1	11	50.70	1	46	33.96
	37	97.30	1	12	50.00	1	47	33.64
	38	94.74	1	13	49.31	1	48	33.33
	39	92.31	1	14	48.65	1	49	33.03
	40	90.00	1	15	48.00	1	50	32.72
	41	87.80	1	16	47.37	1	51	32.43
	42	85.71	1	17	46.75	1	52	32.14
	43	83.72	1	18	46.15	1	53	31.86
	44	81.82	1	19	45.57	1	54	31.58
	45	80.00	1	20	45.00	1	55	31.30
	46	78.26	1	21	44.44	1	56	31.03
	47	76.60	1	22	43.90	1	57	30.77
	48	75.00	1	23	43.37	1	58	30.50
	49	73.47	1	24	42.86	1	59	30.25
	50	72.00	1	25	42.35	2	0	30.00
	51	70.59	1	26	41.86	2	3	29.26
	52	69.23	1	27	41.38	2	6	28.57
	53	67.92	1	28	40.91	2	9	27.90
	54	66.67	1	29	40.45	2	12	27.27

1	55	65.45	1	30	40.00	2	15	26.66
	56	64.29	1	31	39.56	2	18	26.08
	57	63.16	1	32	39.13	2	21	25.53
	58	62.07	1	33	38.71	2	24	25.00
	59	61.02	1	34	38.30	2	27	24.49
	0	60.00	1	35	37.89	2	30	24.00
	1	59.02	1	36	37.50	2	33	23.53
	2	58.06	1	37	37.11	2	36	23.07
	3	57.14	1	38	36.73	2	39	22.64
	4	56.25	1	39	36.36	2	42	22.22
	5	55.38	1	40	36.00	2	45	21.81
	6	54.55	1	41	35.64	2	48	21.42
	7	53.73	1	42	35.29	2	51	21.05
	8	52.94	1	43	34.95	2	54	20.69
	9	52.17	1	44	34.61	2	0	20.00
	10	51.42	1	45	34.28	3		

MEMORANDA

This image shows a single page of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or printed text on the page.

MEMORANDA

259

MEMORANDA

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MEMORANDA

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MEMORANDA

21-2

MEMORANDA

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**Promotion
Advancement in Salary
and
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**Secured
Through the
Automobile Running
Gas Engines**

**COURSES OF INSTRUCTION
OF THE
International
Correspondence Schools**

**International Textbook
Company, Proprietors**

SCRANTON, PA., U. S. A.

Making Three Times as Much as Formerly

One of the great advantages of an I.C.S. Course in automobile work is the fact that it will teach a man quickly much that he cannot get by practical experience. In this connection the following message from Mr. Melvin W. Cox is interesting. Mr. Cox says: "The Course has shown me things that it would be impossible for the garage man to take time to show any one; it tells one the secrets that the automobile repair man will not give away; and it goes into detail of every subject. It has been a thorough and very cheap Course in the end, and I am sure that any one who studies it will learn a good deal more than they expected to find out. I am now General Repair Man and am making three times as much as I was getting at the time of enrolling."

MELVIN W. COX,

188 Kingsboro Ave., Gloversville, N. Y.

Mr. Cox at the time of writing this letter was only 17 years of age, and for a boy of his age has done exceedingly well.

Lathe Hand Becomes Auto- mobile Mechanic

When I enrolled for your Course I knew practically nothing of the working part of an automobile. I had nothing more than a grammar school education at the time of enrolling and was working as a lathe hand. Today I am an Automobile Mechanic at an increase in salary of 50 per cent.

CARL OLTMANNS,

1230 East 71st St., Cleveland, Ohio

Doesn't Have to Beat Around the Bush

MR. CHARLES C. CLIFFORD, JR., of Kenmore, N. Dak., is one of the two million stalwart young men whom the country called into its army several years ago. Upon his return he took up automobile work, and it was not long before he became the owner of an Electric Service Station. In speaking of our Course, he says:

"Your Course has been of aid to me by giving me fuller confidence in myself. On every subject I have covered I can show a customer the cause or explain it, as well as the effect. I do not have to beat around the bush when asked 'why this does that' or when any other question in regard to ignition systems is put to me."

Service Foreman at \$300 a Month

When I started your Course I had a number of years' experience but gained several valuable points from your instruction which was well worth the price I paid for the Course. I will never hesitate to recommend I.C.S. instruction to any one who has ambition to get ahead of the ordinary man. I was an automobile mechanic at the time of enrolling and now I am Foreman of Service for the Altoona Overland Company at a salary of \$300 a month. I had nothing more than a common school education at the time of enrolling.

LUTHER E. LASHLEY,
606 13th St., Altoona, Pa.

Cleared Up Many Hazy Ideas

Considering the small amount of time that I have spent on your Course, I confess it has been very profitable to me. It has cleared up many hazy ideas about certain working parts of an automobile, and explained various types of automobile parts. I am thankful for the thoughtful letters the Schools have written me in connection with this Course. I was a helper at the time of enrolling, now I own a one-third interest in a garage.

WARREN A. GREENLEE,
Quincy, Wash.

Our student may study as his time will permit. Notice how well Mr. Greenlee has done in spite of the fact that he had little time. Why can't you do just as well as he?

Machinist Becomes Garage Manager

The automobile field offers splendid opportunities for advancement and success—first-class opportunities to go into business on your own account or to work as Foreman, Manager, etc. In this connection MR. CULVER S. BROWN, of Granville, N. Y., writes as follows:

"Your Course has been of great help to me in my work. My salary has been doubled since I began to study with you and it was not long before I was promoted to Superintendent."

Mr. Brown is now managing his own garage and his earnings have increased 100 per cent. All of which proves that when it comes to getting the right kind of a salaried position or going into business for yourself the I.C.S. Course will help.

San Francisco Man Stops Guessing

The Automobile Electric Equipment Course has enabled me to graduate from a "guessing" mechanic to one who really knows why and how to accomplish results.

MANGUS A. TRUKKEN,
706 Polk St., San Francisco, Calif.

As a result of instruction received from the Course Mr. Trukken, who had only a grammar school education at the time of enrolling, has become Foreman of the garage of Bert F. Gibbs at San Francisco. His salary is more than twice what he was receiving at the time he began to study his Course. Any person interested in making good in automobile work should read once more his statement that the Course has enabled him to graduate from guesswork to the point where he knows how. The difference between guesswork and knowing how is the difference between an ordinary job and a first-class position in automobile work. The best positions go to the men that know how.

Salary Nicely Increased

When I arrived home from France I was not able to take up my own position as an Electrician, so I started as a Motor Assembler and worked from the cylinder block until I was putting on the fan, which was the last operation. I am now working in a shop where they make the four-cylinder block for the Overland Company; have been here two months, have had two increases in salary, and am now Final Inspector and expecting a higher position shortly. I would like to have you notify my employer of my progress.

ERNEST W. DIGGINS,
27 Clark St., Pontiac, Mich.

Mr. Diggin's request that we notify his employer of the progress he is making in his Course is in line with an offer we make to every student. The student who wants any person informed of the progress he is making in his Course has only to request it of us, and the notifications will be sent from time to time without charge.

Took the Puzzle Out of the Electrical Part

MR. ROSS E. HOUGH, of Arcata, Calif., is Foreman in a garage in that city. He says, "When I enrolled for your Course the electrical parts of an automobile were quite a puzzle to me. The study of the Course has made all this clear. I use your texts frequently and I have always been able to find the desired information. I consider the texts worth more than the price of the Course."

Our Automobile Courses are easy to learn, easy to remember, and easy to apply, and they have enabled many a man to take the puzzle out of the work. In fact, we are constantly in receipt of letters from students telling how the Course has helped them in their work and in increasing their earnings. We feel sure you will be equally enthusiastic if you enroll with us.

Making Good With the Buick

My Course has been of benefit to me in many ways. I am now able to make all repairs on Buick automobiles, electrical as well as others. The Course has also taught me to trace motor and generator circuits, to read wiring diagrams, and read intelligently automobile trade magazines, etc. I could not have done this without your Course—in fact without the Course I would still be back working in the same old way as the fellows are with whom I started. I expect my advancement from now will be very rapid. When I get stuck I go to my Course and always find the answer. The man that studies is the man that succeeds.

FRED H. ERVANS,
224 E. First St., Flint, Mich.

No Trouble With Electric Equipment Since Studying Course

Many men engaged in automobile work have more or less trouble in making repairs on electric equipment, but I.C.S. students in various parts of the country are making good in this kind of work. MR. JAMES G. STRINGER, of 546 E. President St., Savannah, Ga., says: "Your Course has helped me to better understand the electric equipment on automobiles and to repair them. I don't have any trouble locating ignition troubles and repairing them. The instruction texts are very good reference when puzzled on any job."

Mr. Stringer is now Foreman of the garage of the Adams Motor Company. This is a very good position in which his Course will help him.

Foreman in Big Hotel Garage

Many of the big hotel clubs of the country have garages of their own and foremen of such garages generally make mighty good money. One of these foremen is Mr. Claude E. Jacques, of Del Monte, Calif. Mr. Jacques says: "The benefits received from your Course in Automobile Electric Equipment have made it possible for me to enjoy my present position. The fact that I was an I.C.S. student was a large factor in my securing this position. The Del Monte Hotel caters only to the people of wealth, and consequently I have nothing but high-grade cars to work on. I am making eight times as much money as I was getting at the time of enrolling."

CLAUDE E. JACQUES,
Foreman, Hotel Del Monte Garage,
Del Monte, Calif.

Belotti Makes Good as Repair Man

All I know about automobiles I owe to the International Correspondence Schools Course. The instruction is of great value. I was a common laborer at the time of enrolling and now I am an Automobile Repair Man.

V. Z. BELOTTI,
Box 254, Clinton, Mass.

Mr. Belotti as a graduate of the International Correspondence Schools, as you have already seen, credits all he knows about automobiles to the instruction received from the Course. He had only a common school education at the time of enrolling. So here we have another proof of the statement that a young man who really wants to get ahead may do so if he gives himself a square deal. An I.C.S. Course will help him. The most important thing to do is to enroll at once and get started.

Another Westerner Owns Automobile Electric and Service Company

Your Course has given me a good education in mechanics. Through its help I was able to pass an examination for commission in United States Navy as Engineering Ensign; later to go to the United States Naval Academy, graduating from there as one of the high men in a class of four hundred.

I find all the instruction in the I.C.S. Course clear, concise, and quite easily understood. I was a helper at the time of enrolling. Today I am owner of an Automobile Electric and Service Company doing electrical and mechanical repairing and employing a number of men. My education at the time of enrolling with you consisted of only 2 years in a grammar school.

EDWARD J. PERRIN,
319 Central Avenue, Lodi, Calif.

Designer and Builder of Auto Fixtures

I have made wonderful progress since taking my I.C.S. Course, which I highly recommend to any one. I had a good grounding in the automobile business, but found myself at a standstill until I enrolled. Since then my progress has been rapid. For some time I worked as Assistant Foreman of the Gear Department of the Buick Motor Company. Later I became identified with the Mason Motor Company, designing and building fixtures. I expect to go into business for myself soon on the basis of what I learned from the I.C.S.

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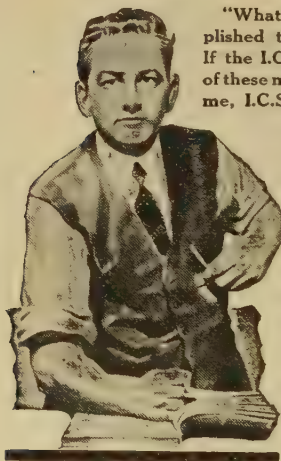
Recently, when asked for a statement concerning the one thing that had contributed most to his success, he said:

"I believe the greatest source of assistance and encouragement came to me when I became interested in trying to better my position. I wanted an education—that is, a foundation on which to build. So I enrolled as a student in the Mechanical Engineering Department of the International Correspondence Schools, of Scranton, Pa., and began to study. There is no question in my mind but that was the most important step of my life."

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